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Description of SHARC, The Strategic High-Altitude Radiance Code

R.D. SHARMA
A.J. RATKOWSKI
R.L. SUNDBERG
J.W. DUFF
L.S. BERNSTEIN
P.K. ACHARYA
J.H. GRUNINGER
D.C. ROBERTSON
R.J. HEALEY

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GEOPHYSICS LABORATORY
HANSCOM AFB, MA 01731-5000

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

(Signature)
Dr. A. J. RATKOWSKI
Branch Chief

FOR THE COMMANDER

(Signature)
Dr. R. EARL GOOD
Division Director

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R. D. Sharma, A. J. Ratkowski, R. L. Sundberg*, J. W. Duff*, L. S. Bernstein*, P. K. Acharya*,

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The Strategic High-Altitude Radiance Code (SHARC) is a new computer code that calculates atmospheric radiation and transmittance for paths from 60 to 300 km altitude in the 2-40 μm spectral region. It models radiation due to NLTE (Non-Local Thermodynamic Equilibrium) molecular emissions. This initial version of SHARC includes the five strongest IR radiators, NO, CO, H_2O, O_3, and CO_2. This report describes the code and models used to calculate the NLTE molecular populations and the resulting atmospheric radiance. The SHARC Manual is reproduced in the appendix.

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12. Personal Authors (Continued)

J. H. Gruninger[*], D. C. Robertson[*], and R. J. Healey[+]

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1. INTRODUCTION

The Strategic High-Altitude Radiance Code (SHARC) is a new computer code for calculating atmospheric infrared radiation between 60 and 300 km altitude. Arbitrary paths such as slant, vertical and limb above 60 km are allowed. This initial version of SHARC calculates ambient radiation between 2 and 40 μm that arises from the five strongest infrared (IR) radiators, NO, CO, H_2O, O_3 and CO_2.[1] Effects due to the NLTE (Non-Local Thermodynamic Equilibrium) populations of higher vibrational states are included in the calculation. The equivalent-width, line-by-line (LBL) approach for radiation transport along the line of sight (LOS) gives a spectral resolution of about 0.50 cm^{-1}. The code is relatively fast running, has a user-friendly input module and is suitable for systems-type calculations.

Modular construction and supporting data files have been emphasized in the development of SHARC so that models and model parameters can be modified or upgraded as additional data and/or better models become available. The input module queries the user for needed parameters and performs a first-order check on the internal consistency of the requested parameters. The geometry module reads in the needed atmospheric parameters and determines the trajectory of the requested path through the atmosphere. Excited state populations are calculated by interfacing a Monte Carlo model for radiative excitation and energy transfer[2] with a highly flexible chemical kinetics

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(Received for Publication 14 August 1989)

1. Sharma, R. D., Ratkowski, A. J., Sundberg, R. L., Duff, J. W., Bernstein, L. S., Acharya, P. K., and Robertson, D. C., SHARC: A Computer Model for Calculating Atmospheric Radiation Under Non-Equilibrium Conditions, AFGL-TR-89-0083 (March 1989). AD A206236

2. Bernstein, L. S., Non-Equilibrium Molecular Emission and Scattering Intensity Subroutine (NEMESIS), AFGL-TR-88-0124 (1988). AD A199295

module derived from the Sandia CHEMKIN Code.[3] The radiation transport module performs line-by-line (LBL) calculations based on an equivalent-width formulation for the total line radiance.

SHARC is a successor to the AFGL HAIRM Code.[4,5] Both codes are based on analyses of various AFGL lab and field measurements for these radiative processes. SHARC incorporates several advances. Its chemical kinetics package is based on a completely general, time-dependent equation solver, and its reaction scheme is fully accessible to the user via external data files. The coupling of the radiative excitation and chemical kinetics modules provides the means for a better calculation of populations for the higher vibrational levels. Radiative transfer calculations for the observer LOS employ a full Voigt profile rather than just the Doppler. Presently, SHARC uses the AFGL HAIRM data base for its chemical kinetics and atmospheric profiles.[4] The molecular line parameters are taken from the current HITRAN line atlas[6] and supplemented with additional lines for the high vibrational states for $O_3(\nu_3)$ in the 10-12 μm spectral region.[4] As additional data are analyzed, the appropriate parameters in the SHARC data base will be upgraded. This upgrade ability plus SHARC's flexible geometry package and interactive input module represent significant advances over HAIRM.

A general introduction to NLTE radiation and the important infrared-active molecules is given in the next section, with an overview of

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3. Kee, R. J., Miller, J. A., and Jefferson, T. H., CHEMKIN: Problem-Independent, Transportable, Fortran Chemical Kinetics Code Package, Sandia Report No. SAND80-8003, Sandia National Laboratory, Livermore, CA 94550 (March 1980).

4. Degges, T. C. and D'Agati, A. P., A User's Guide to the AFGL/Visidyne High Altitude Infrared Radiance Model Computer Program, AFGL-TR-85-0015 (1984). AD A161432

5. Sundberg, R. L., Robertson, D. C., Sharma, R. D., and Ratkowski, A. J., HAIRM-87 A High Altitude Infrared Radiance Model," AFGL-TR-88-0014 (1988). AD A197637

6. Rothman, L. S., Gamache, R. R., Goldman, A., Brown, L. R., Toth, R. A., Pickett, H. M., Poynter, R. L., Flaud, J. M., Camy-Peyret, C., Barbe, A., Husson, N., Rinsland, C. P., and Smith, M. A. H., "The HITRAN Database: 1986 Edition," Appl. Optics, 26, 4058 (1987).

SHARC in Section 3. Sections 4-7 give description of the GEOMETRY, CHEMKIN, NEMESIS and SPCRAD modules, respectively. Illustrative calculations are shown in Section 8 and conclusions are presented in Section 9. User instructions are given in the appendix.

2. ATMOSPHERIC INFRARED RADIATION AT HIGH ALTITUDES

2.1 Non-Local Thermodynamic Equilibrium

Before discussing IR radiators in the upper atmosphere, we introduce the very important concept of non-local thermodynamic equilibrium (NLTE). Figure 1 shows the number of collisions a molecule suffers per second as a function of altitude. The relevant inputs, density, temperature, etc., are taken from the U.S. Standard Atmosphere. The number of collisions decreases rapidly as a function of altitude. This fact influences the high-altitude IR airglow in a profound way. This can be seen as follows: At steady state the ratio of the density of a vibrationally excited species $[M^*]$ to the density of its ground state [M] is given by

$$[M^*]/[M] = (P_c+J)/(L_c+A) \quad , \qquad (1)$$

where P_c and L_c are the terms for production and loss, respectively, of M^* due to collisions, J is the radiative pumping term due to absorption of radiation from earthshine, sunshine and the atmosphere, and A is the radiative loss term or the Einstein A Coefficient for spontaneous emission. When the collisional production and loss processes are much faster than the radiative ones,

$$[M^*]/[M] = P_c/L_c = \text{Equilibrium Constant (K)} \qquad (2)$$

and thermodynamic equilibrium holds. Under these conditions infrared airglow emitted by M^* can be described by the black body laws at the local equilibrium temperature (LTE). When the radiative terms are not negligible compared to the collisional terms and Equation (2) can no longer be used to describe the situation, thermodynamic equilibrium no longer prevails. The situation is said to be described by non-local thermodynamic equilibrium (NLTE). A rule of the thumb is that the radiation begins to deviate from LTE when there are less than a million collisions per radiative lifetime. The radiative lifetime of the v=1 state of NO is about 0.1 s, so the 5.3 μm radiation from NO begins to deviate from equilibrium around 40 km altitude. The radiative bending mode of CO_2 (ν_2) has a lifetime of about 0.67 s, so the 15 μm emission from CO_2 may be described by LTE up to 65 km altitude. This is an approximate but helpful rule which is applicable to species that are not produced by chemiluminescence or photodissociation. At very high altitudes the radiative pumping and loss terms J and A in Equation (1) are much larger than the collisional pumping and loss terms P_c and L_c. The ratio of the excited to ground state densities then becomes

$$[M^*]/[M] = J/A \quad . \tag{3}$$

This situation is described as "radiative equilibrium". At altitudes greater than about 150 km the ratio of the densities of the CO_2 vibrational levels 01^10 and 00^00 is determined solely by the upwelling earthshine. The frequency of collisions is too small to have any impact.

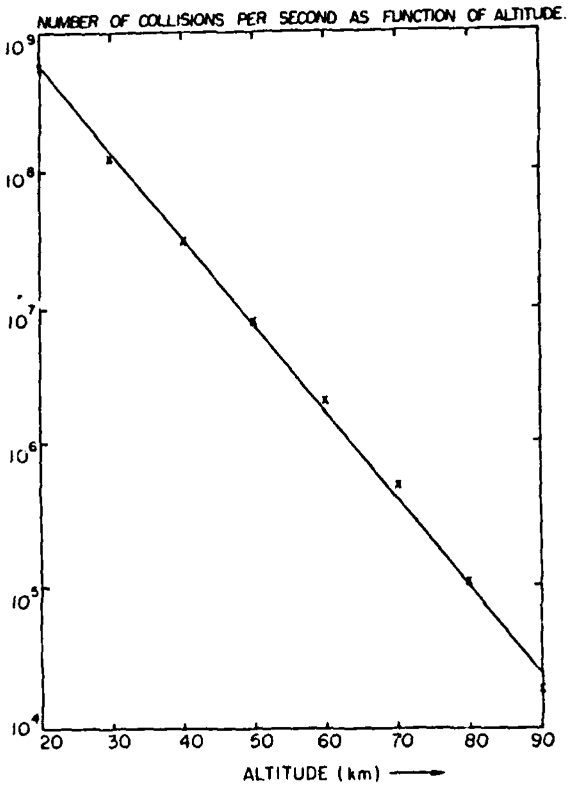


Figure 1. The Number of Collisions Suffered by an Atom or Molecule per Second as a Function of Altitude.

The arguments cited above apply to stable species for which normally only the lowest vibrational level is populated and which may be excited by earthshine, sunshine, and collisions. They are not applicable to the species produced by chemiluminescence (OH and O_3) and by photodissociation (the singlet delta excited electronic state $^1\Delta_g$ of O_2). In such cases the pumping and loss terms in Equation (1) become more complicated because vibrationally excited levels may be populated by chemical reactions or by photodissociation and these levels can influence the production or loss processes of other levels. We then have a number of coupled equations instead of the simple Equation (1). Nevertheless, Equation (1) nicely illustrates the basic points involved in calculating the ratio of the excited (upper) to ground (lower) state density.

2.2 Vibrational Temperature

At this point it is useful to introduce the concept of a vibrational temperature. This concept is based upon the experimental observation that translation to vibration (T-V) energy transfer rate coefficients are usually much smaller than translation to rotation (T-R) rates or the near resonant vibration to vibration (V-V) rates. Whereas T-V and T-R rates equilibrate translational degrees of freedom with vibrational and rotational degrees of freedom respectively, the V-V near resonant rates lead to the establishment of a Maxwell-Boltzmann distribution in a given vibrational manifold. We then have a situation where the translational and rotational degrees of freedom can be described by one temperature and the vibrational levels in a given vibrational manifoid are described by an entirely different temperature. Of course two different vibrational manifolds in the same molecule may be described by two different vibrational temperatures. For example, the ν_2 and ν_3 vibrational modes of CO_2 in NLTE situations invariably have different vibrational temperatures. If two vibrational modes are coupled by the Fermi or Dennison resonances, they may rapidly equilibrate and have the same vibrational temperatures. Again, ν_1 and ν_2 modes of CO_2 coupled by their Fermi resonance are believed to have the same vibrational temperature. The vibrational temperature T_v is defined by the relation

$$T_V = (1/c_2E) \ln(g_e n_\ell / g_\ell n_e) \quad (4)$$

where g_e and g_ℓ are the statistical weights of the excited and lower states and n_e and n_ℓ are their respective number densities. E is the vibrational spacing between the two levels in cm^{-1}, and c_2=1.4388 $^oK/cm^{-1}$ is the second radiation constant. The temperature or population of the upper state is usually defined relative to the population of the ground state, that is, ℓ is the ground state. It is clear from Equation (4) that T_V becomes equal to the translational temperature T when thermodynamic equilibrium prevails. Defining a vibrational temperature has proven to be a useful concept because it not only indicates departure from equilibrium but also the extent of this departure. It should, however, be pointed out that the concept of a single vibrational temperature cannot always be applied to describe the populations of all vibrational levels. For example, the vibrational populations of the OH radical produced by chemical reactions around 80 km altitude (the hydroxyl layer) cannot be described by a vibrational temperature.

The lack of collisions leads to departure from equilibrium (NLTE situations), but more frequent collisions do not guarantee thermodynamic equilibrium. This point is illustrated by the solar pumped airglow which, for bands like the 2.7 μm CO_2, can establish a steady state population of excited molecular levels higher than those given by LTE as far down as 50 km altitude.

2.3 Molecular Radiators

Currently SHARC supports the main isotopes of CO_2, NO, O_3, H_2O and CO. In future versions, we plan to incorporate minor isotopes as well as OH. We define natural conditions to be the quiescent and aurorally disturbed atmosphere; auroral radiation is currently being incorporated and will be available in the next version of SHARC. Atmospheric radiation in this wavelength interval arises from either vibration-rotation transitions of these molecules or from pure rotational transitions of OH and H_2O. Pure rotational transitions of NO, CO and O_3 occur farther towards the red, around 100 μm, because these molecules have large moments of inertia; these transitions for CO_2 are unallowed because it has no permanent dipole moment. It should be pointed out that the abundant species N_2 and O_2 have no IR vibration-rotation or rotation spectrum because of the absence of both transition and permanent dipole moments.

The primary source of information about the intensity and location of the spectral lines is the HITRAN data tape.[6] It contains virtually all of the important lines for LTE conditions, but additional lines were added for NLTE transitions from higher vibrational levels of the $O_3(\nu_3)$ band.[4] The total intensity of the various bands is given by their usual Einstein A coefficients, which are related to the HITRAN absorption coefficient $S_{u\ell}$ (cm^2/molecule) tape by the equation

$$A = (8\pi c \nu^2 S_{u\ell})/g_u \sum \exp(E_\ell/205.727)/Q \quad , \tag{5}$$

where the sum is over rotational levels and Q is defined by

$$Q = 1 - \exp(-\nu/205.727) \quad , \tag{6}$$

ν being the frequency of the transition in wavenumbers. In Equation (5) g_u is the degeneracy of the upper level, E_ℓ is the energy of the lower level in cm^{-1}, and 205.727 is the energy in wavenumbers corresponding to the standard temperature 296°K for the HITRAN tape. The absorption coefficient $S_{u\ell}$ obtained from the HITRAN tape contains the vibrational partition sum, the natural abundance of the isotopes and the Boltzmann factor $g_\ell \exp(-E_\ell/205.727)$ for the population of the lower level.

2.3.1 CO_2

Figure 2 shows the important CO_2 transitions observed in the infrared. There are three sets of strong transitions, which result in bands around 15.0, 4.3, and 2.7 μm. The relative strengths of the most important bands of these transitions are determined from their Einstein A coefficients. Some illustrative SHARC values are given in Table 1.

Around 15 μm, the bands result from a change of one quantum of bending mode ν_2. These transitions are very prominent in the emission from the earth's atmosphere and the sharp Q-branch can be clearly seen in spectra of the earth taken with resolutions of a few wavenumbers from a balloon, rocket

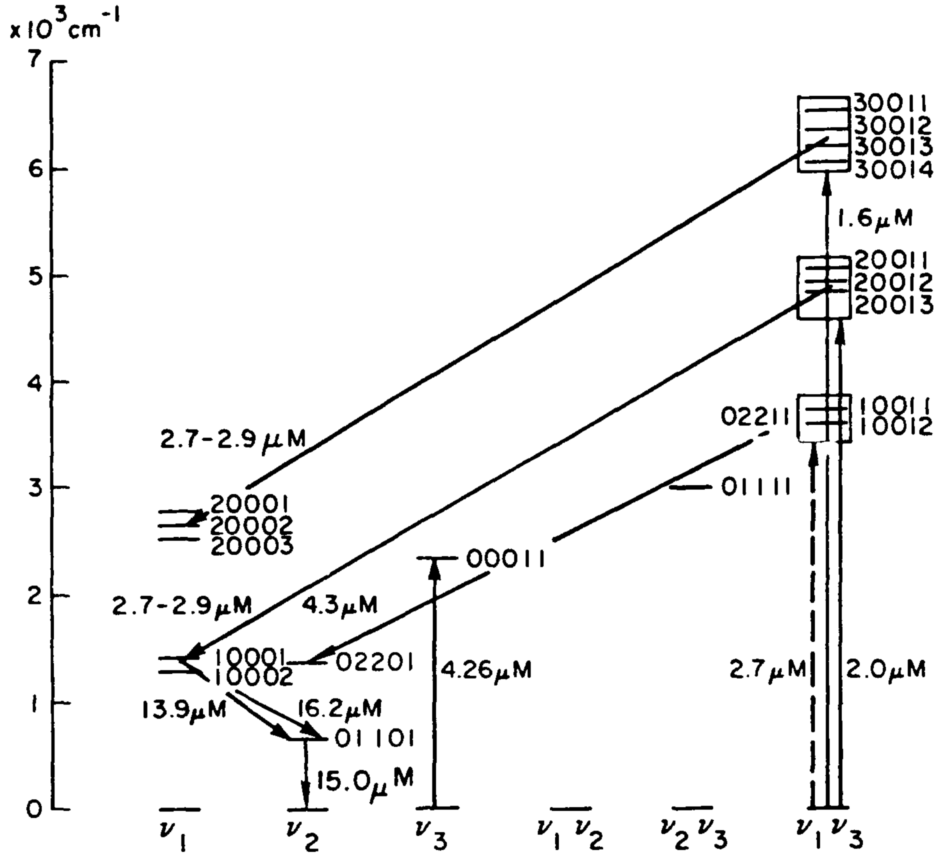


Figure 2. Important CO_2 Airglow Transitions and the Energy Levels Connecting them.

or satellite.[6,7] The reason for this is very simple. The spectrum of a 300°K blackbody peaks near 10 μm. Therefore, there are large numbers of 15 μm photons in the radiation, termed earthshine, emitted by the earth's atmosphere as well as by the earth itself. Since the 15 μm CO_2 band is very strong, its transitions to the ground state and low lying excited states are severely self-absorbed. This fact has important consequences for atmospheric radiation which we will point out as we go along. Similarly, solar radiation has negligible influence on the 15 μm radiation because of the small number of solar photons at this wavelength. The intensity of 15 μm radiation therefore

7. Stair, A. T., Jr., Sharma, R. D., Nadile, R. M., Baker, D. J., and Grieder, W. F., "Observations of Limb Radiance with Cryogenic Spectral Infrared Rocket Experiment (SPIRE)," J. Geophys. Res., 90, 9772 (1985).

Table 1. Illustrative Einstein A Coefficients for CO_2

Upper State	Lower State	Energy (cm^{-1})	Einstein A Coefficient (s^{-1})
$10^0 02$	$01^1 01$	618.	1.158
$01^1 01$	$00^0 01$	667.4	1.516
$02^2 01$	$01^1 01$	667.8	3.064
$10^0 01$	$01^1 01$	721.	1.578
$00^0 11$	$10^0 01$	961.	0.4448
$00^0 11$	$10^0 02$	1064.	0.4693
$00^0 11$	$00^0 01$	2349.	434.17
$10^0 12$	$00^0 01$	3613.	11.176
$10^0 11$	$00^0 01$	3715.	17.951

shows no diurnal variation.[8] The second band, around 4.3 μm, arises from the emission of a quantum from the asymmetric stretch ν_3. Because earthshine does not contain a strong 4.3 μm component, this band is much stronger during daytime. Solar radiation at 4.3 μm, 2.7 μm, 2.0 μm, and 1.6 μm is absorbed followed by a large probability of emission at 4.3 μm.[9] The probability of emission is largest at 4.3 μm because of the much larger Einstein A coefficients (Table 1) than those at 2.7 μm. The probability of reemission at 2.0 and 1.6 μm is negligible because of very small A coefficients. Transitions near 4.3 μm to the ground state and also to the low lying excited states are severely self-absorbed too. The third band, around 2.7 μm, is due to emission from combination bands of $\nu_1+\nu_3$. This emission, even more than the 4.3 μm component, is predominantly observed from the sunlit atmosphere. The nighttime atmosphere of the earth has not been observed to emit this radiation because of the large energy of the 2.7 μm photon.

8. Handbook of Geophysics and the Space Environment, A. S. Jursa editor, Geophysics Laboratory, Hanscom AFB, MA 01731 (1985). ADA 167000

9. Nebel, H., Sharma, R. D., Wintersteiner, P. P., and Joseph, R. A., "CO_2 (4.3 μm) Vibrational Temperatures and Limb Radiances under Sunlit Conditions in the 50-120 km Altitude Range," EOS, Proceedings of the American Geophys. Union, Fall 1989, San Francisco, CA, To Be Published.

2.3.2 NO

Nitric oxide is a prominent radiator in the high altitude atmosphere. The 5.3 μm emission from its (1-0) vibrational transition is the most efficient atmospheric cooling agent between about 100 and 150 km altitude. The reason for this is the efficient transfer of translational energy into vibrational energy during collisions between NO and atomic oxygen. The reverse V-T process has an almost gas kinetic cross-section at room temperature. The 5.3 μm emission from NO in the thermosphere is so bright that stratospheric limb radiance calculations that do not include NO emission in the thermosphere nor the excitation of these NO bands by thermospheric emission are likely to be incorrect.

2.3.3 O_3

The nonlinear triatomic molecule O_3 has three vibrational degrees of freedom. The vibrational mode ν_1 at 1103 cm^{-1} has an Einstein A coefficient of about 0.5 s^{-1} compared to about 10 s^{-1} for the ν_3 mode at 1042 cm^{-1} and about 0.08 s^{-1} for the ν_2 mode at 701 cm^{-1}. Because of its much larger Einstein coefficient, emission from the ν_3 mode is the dominant ozone emission observed from the earth's atmosphere. It is well known that ozone is photodissociated by the ultraviolet component of solar radiation. The three body recombination reaction $O+O_2+M \rightarrow O_3+M$ regenerates ozone during the nighttime. The ozone thus formed is in highly excited vibrational states. In the stratosphere, this newly formed ozone quickly loses its vibrational energy via collisions. However, because of the lower densities in the mesosphere, radiative processes, especially those involving the ν_3 mode, become rapid enough so that emissions from excited vibrational levels are observed in the 10-13 μm region. Identification of levels responsible for this radiation is still not complete, and considerable work needs to be done before a complete model of ozone emission in the mesosphere can be constructed. Because of the decreasing total density, the three-body recombination process becomes slower in the thermosphere, and emission from ozone rapidly decreases.

2.3.4 H_2O

Figure 3 shows the the three fundamental vibration-rotation transitions of water vapor and the important combination and difference bands. Only transitions near 6.3 μm are observed in the nighttime atmosphere. Transitions near 2.7 μm and 4.85 μm originate from the vibration-rotation levels pumped by solar radiation. Vibration-rotation bands of water have a very complex rotational structure arising from the fact that water is an asymmetric top molecule with three moments of inertia. Further, these moments of inertia are small and the fact that water has a large permanent dipole moment leads to the rich rotational spectrum in the *18-40 μm region. One possible source of* excitation of these vibration-rotation levels is the accidental resonance of these levels with the nighttime emission from hydroxyl. This source has thus far not been shown to be the cause of any infrared radiance.

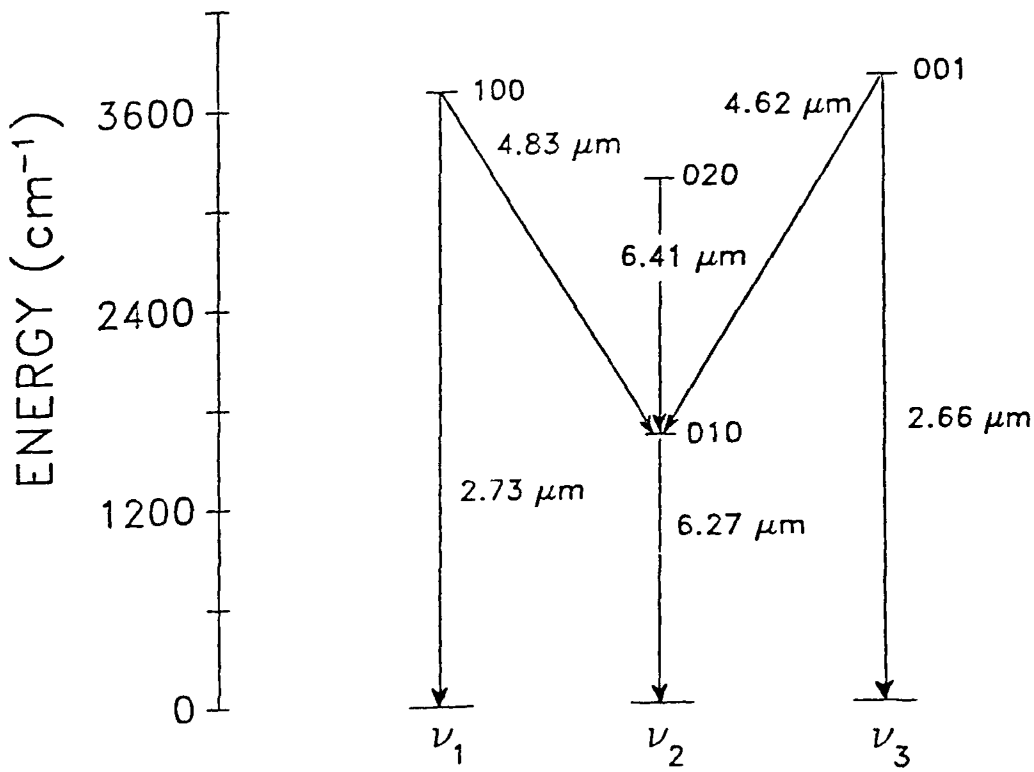


Figure 3. H_2O Transitions for the Lower Energy Levels That Contribute to Atmospheric IR Radiance at High Altitudes.

2.3.5 CO

CO is another important atmospheric radiator because of its presence up to altitudes up to 300 km. It is vibrationally excited by emission from the earth's surface and emission from the stratosphere during the night; during the day excitation by sunshine also plays an important role. CO vibrational excitation is not as closely tied to that of N_2 as is that of asymmetric stretch ν_3 of CO_2.

2.3.6 OH

Although not in the present version of SHARC, OH is included in this discussion because it is scheduled be added at a later date. The OH radical is produced around 85 km primarily by the reaction

$$H + O_3 \rightarrow OH + O_2 \quad , \tag{7}$$

and secondarily by the reaction

$$O + HO_2 \rightarrow OH + O_2 \quad . \tag{8}$$

Both these processes produce vibrationally excited OH, with the first reaction producing excitations up to the ninth vibrational level. OH is one of very few molecules for which multiquantum radiative transitions are allowed. One can therefore detect the $\Delta\nu=1$ transition near 2.7 μm, and the higher $\Delta\nu$ transitions extend all the way up to visible frequencies. These vibrational transitions, for historical reasons are called Meinel bands. The measurement and calculation of the Einstein A coefficient of OH is a very current research topic. The following values for the rotationless A coefficient determined by Nelson, Schiffman and Nesbitt are given in Table 2.[10] The table shows that these numbers do not scale according to the usual $A_{\nu'\nu-1} = \nu A_{1'0}$ rule, and that multiquantum transitions are weaker than single quantum ones.

10. Nelson, D. D., Schiffman, A., and Nesbitt, D. J., "The Dipole Moment Function and Vibrational Transition Intensities of OH," J. Chem. Phys., 90 5455 (1989)).

Table 2. OH Rotationless Einstein A Coefficients[10]

Vibrational Transition	Einstein A Coefficient (Hz)
1-0	16.7
2-1	21
3-2	17
2-0	11
3-1	31
4-2	58

3. SHARC OVERVIEW

The five major SHARC modules are run sequentially. The only exceptions are the NEMESIS and CHEMKIN modules, which are frequently run iteratively in calculating populations for the higher excited states of some molecules like CO_2 and O_3. The major code modules are shown in the schematic of Figure 4. The main-driver module opens and closes files and links the modules. The input module, which is interactive and menu-driven, prepares the input file for the rest of the code; it is shown in Figure 4 as the INTERACTIVE block. The next step is calculation of the excited-state NLTE populations by the chemistry module. It iterates between a generalized chemical kinetics module that calculates excited-state populations due to solar and earthshine

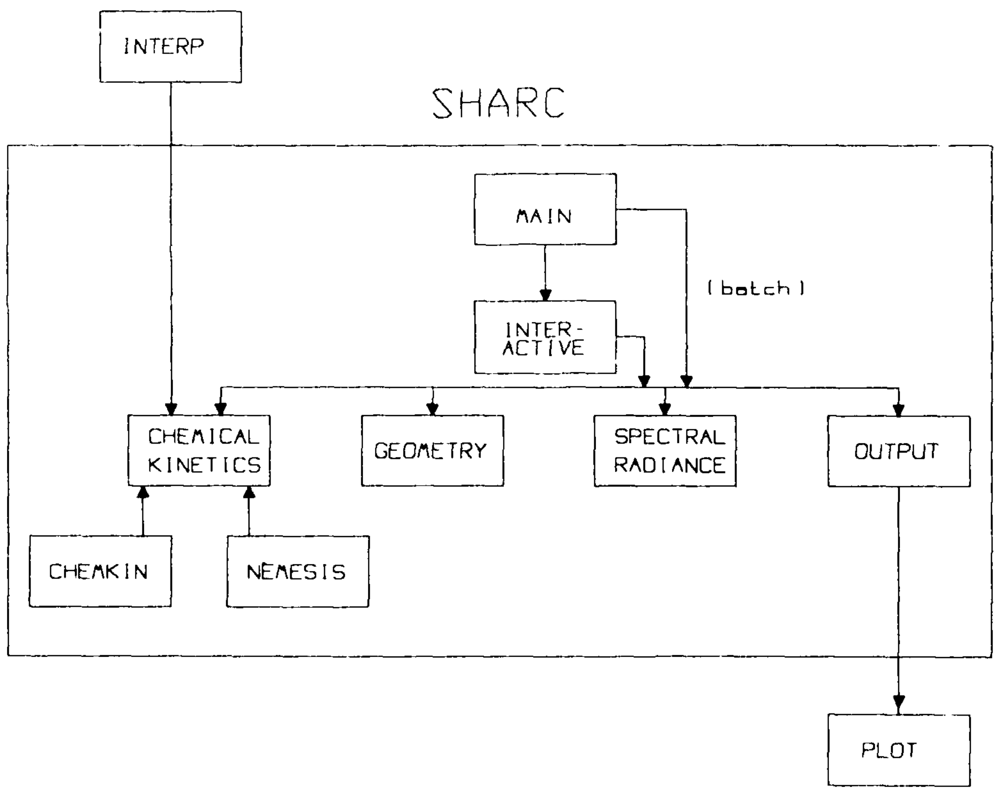


Figure 4. Schematic Showing the SHARC Modules and Calculational Flow.

excitation, and a radiative excitation model that calculates radiation transport between atmospheric layers. The geometry module determines ground- and excited-state populations or column densities for each layer traversed by the user's requested path. The radiative transport module then calculates the spectral radiance along the LOS. The calculation is done on a line-by-line (LBL) basis in that the total radiation from each line is calculated using an equivalent-width formulation from band-model theory[11] that incorporates Doppler-Lorentz (Voigt) lineshapes. Finally the results are passed to a separate plotting module that prepares a spectral plot of the calculated radiance.

11. Ludwig, C. B., Malkmus, W., Reardon, J. E., and Thomson, J. A., Handbook of Infrared Radiation From Combustion Gases, NASA SP-3080, Scientific and Technical Information Office, NASA, Washington DC (1973).

4. GEOMETRIC PARAMETERS AND DESCRIPTIONS

The GEOM module calculates the line-of-sight (LOS) trajectory, related parameters, and column densities of atmospheric gases for subsequent use by other modules. Specifically, GEOM

- Characterizes the LOS trajectory as it passes through the atmosphere;
- Computes the solar direction with respect to earth and LOS;
- Allows multiple input options for LOS and solar parameters;
- Locates the solar terminator; and
- Computes column densities of various atmospheric species along the LOS.

The user has several options for defining the LOS. Much of the GEOM nomenclature and several sections of code are borrowed from the LOWTRAN-6 geometry routines.[12] No knowledge of LOWTRAN 6 is required to use GEOM as it is self-contained. Presently SHARC's atmospheric models or profiles are one-dimensional, that is, the only variations in atmospheric parameters are in the vertical direction (z-axis), and the layers are locally horizontally isotropic (spherically symmetric shells). However, GEOM is sufficiently general so that horizontally varying atmospheric profiles can be accommodated. A curved-earth geometry is used for trajectory calculations; since atmospheric refraction is insignificant under these rarefied conditions, it is not calculated.

12. Kneizys, F. X., Shettle, E. P., Gallery, W. O., Chetwynd, J. H., Jr., Abreu, L. W., Selby, J. E. A., Clough, S. A., and Fenn, R. W., Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 6," AFGL-TR-83-0187 (1983). AD A137796

4.1 Model Atmospheres

The atmosphere is currently divided into 61 layers from 60 to 300 km. For each layer, the pressure, temperature and number densities of the most significant atmospheric constituents, N_2, O_2, O, CO_2, H_2O, NO, N_2O, O_3, and CO are stored in external data files. Currently, the same model atmospheres as the AFGL HAIRM model[4] are incorporated; they are:

- 1976 U.S. Standard Atmosphere;
- 15^o lat annual;
- 30^o " summer, winter;
- 45^o " spring/fall, summer, winter; and
- 60^o " summer, winter

for exo-atmospheric temperatures of 600, 1000, and 1500 K.

4.2 Characterization of the LOS

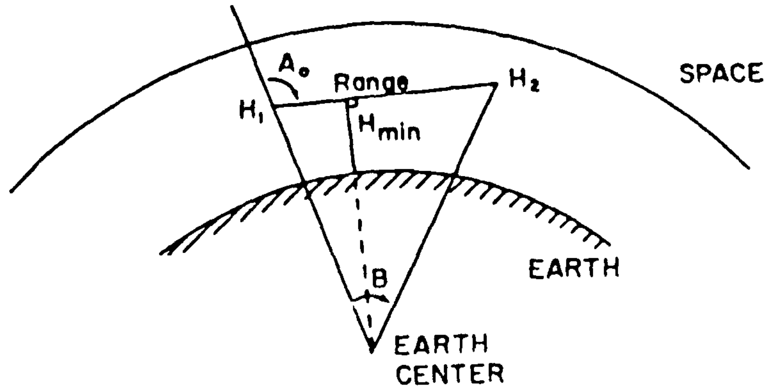
The LOS is a straight line (no refraction) that connects the "observer" and "source." In a sense, radiation "flows" from the source at H2 to the observer at H1. The path is specified when the precise locations of these two points are given in earth coordinates, that is, their latitudes, longitudes, and altitudes. Once these points are located, other needed path parameters are calculated and stored.

The possible paths have been divided into three types defined by the parameter ITYPE. Each requires a variety of information for its definition. Other related parameters are calculated from these input parameters within the code to determine the path direction. The paths, illustrated in Figure 5, are observer to source, observer to space, and limb view These are specified through the IPATH variable and are labeled as follows:

```
IPATH = 2  --  Observer to source,
      = 3  --  Observer to space, and
      = 4  --  Limb view.
```

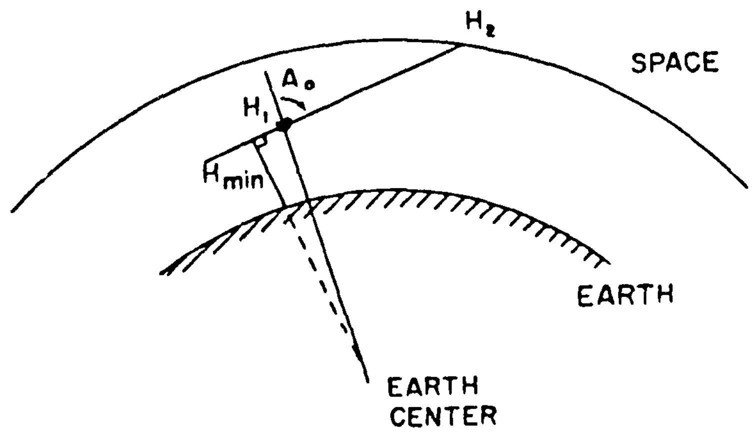
ipath = 2
Observer to Source

Both observer and source in atmosphere



ipath = 3
Observer to Space

Observer in atmosphere source in space



ipath = 4
Limb View

Both observer and source in space

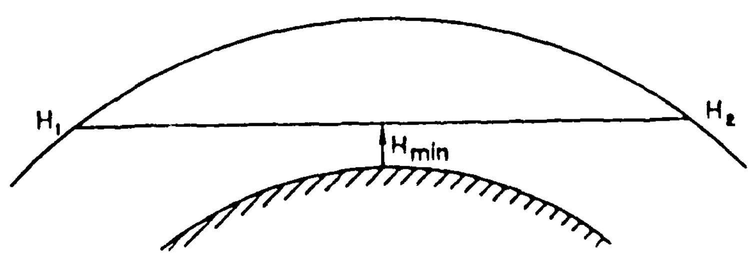


Figure 5. Geometric Definitions of Radiance Paths Through the Atmosphere.

The observer-to-source path is a straight line through the atmosphere from the observer to the source point. The location of the observer (H_1) and the location of the source (H_2) are required inputs. The observer location must be given by its altitude, longitude, and latitude. The source location can be defined either by coordinates relative to the observer or by its altitude, latitude, and longitude.

The observer to space path, IPATH=3, points from the observer through the atmosphere to space in a specified direction. That direction is defined by angles and altitudes. The limb viewing path looks from one edge of the atmosphere to the other at a specified tangent height relative to the earth. The tangent height is the input only parameter necessary to specify the path.

The local zenith angle, A_0, is measured from the vertical line connecting the observer and the earth center to the line from the observer to the source point, and its limits are from 0 to 180°. The azimuth angle is defined in the observer plane and is orthogonal to the zenith angle. The azimuth angle shown pictorially in Figure 6 is the angle between the north pole to observer line and the observer to source line. The azimuth angle, B_0, has a range from -180 to 180 (0°=north, 90°=east). The source-observer angle β is measured from the zenith to the line connecting the source and the center of the earth. β must be greater than zero and is generally a small angle. At large angles (>30 degrees), the observer will view the hard earth.

The range is the distance between the source and the observer. It must be a positive number and the source must stay within the atmosphere. Latitude

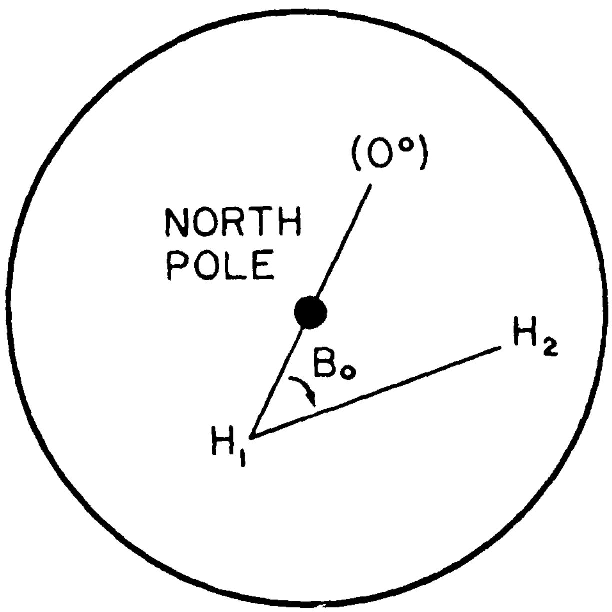


Figure 6. Schematic Illustrating the Definition of the Observer (or Solar) Azimuthal Angle.

and longitude are conventional earth coordinates specified in degrees. The latitude and longitude difference between observer and source must be kept relatively small to prevent the path from approaching too close to the earth. The atmosphere is defined between 60 km and 300 km and, therefore, the altitude and height parameters should be within this range. H_{min} is the height tangent to the path. All altitudes (and heights) are measured from the surface of the earth.

A path from observer to source, with a local zenith, A_0, greater than 90° and range unspecified, requires another parameter in its definition to resolve an ambiguity. For this geometry, Figure 7 illustrates the two possible positions of the atmosphere where the height of the source are the same. Following LOWTRAN,[12] a range parameter, LEN, is defined to distinguish between the short path and the long path. When LEN=0 the short path will be computed and if LEN=1 the long path is chosen.

This length parameter is also necessary for a path from observer to space where the local zenith is unspecified. (See Figure 8.) For case 2 there are two possible paths and LEN is used to distinguish between them. The minimum height, used to specify the direction toward space, shows at what angle the path is going. But the path can either go downward, passing through the H_{min} (LEN=1) or upward, away from H_{min} (LEN = 0).

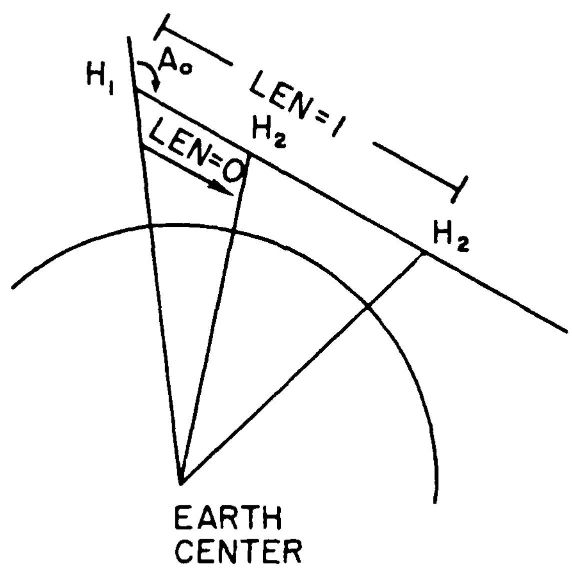


Figure 7. Schematic Showing the Atmosperhic Path for the IPATH = 2.

Definition of Parameters

H_{1alt}	observer altitude
H_{1lat}	" latitude
H_{1long}	" longitude
H_{2alt}	source altitude
H_{2lat}	" latitude
H_{2long}	" longitude
A_0	local zenith angle
B_0	local azimuth angle - measured in plane at observer altitude
RANGE	straight line distance between source and observer
H_{min}	tangent height measured from earth to path
β	earth center angle
LEN	the length parameter for certain down-looking paths

Shown in Table 3 is the information needed to specify the path for each of the path types. The symbol H_1 *stands for the altitude, longitude, and* latitude for the observer position.

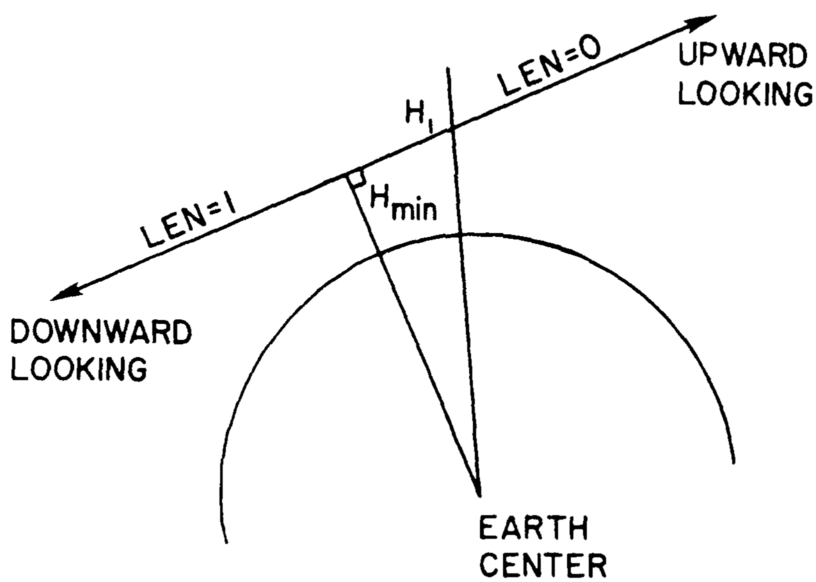


Figure 8. Schematic Showing the Atmospheric Path for the IPATH = 3.

Table 3. Options for Path Definition

IPATH=2	CASE1	H_1, H_{2alt}, A_0, B_0
		H_1, H_{2alt}, A_0, B_0, LEN
	2	H_1, RANGE, A_0, B_0
	3	H_1, H_{2alt}, RANGE, B_0
	4	H_1, H_{2alt}, β, B_0
	5	H_1, H_{2alt}, H_{2long}, H_{2lat}
IPATH=3	CASE1	H_1, A_0, B_0
	2	H_1, H_{min}, B_0, LEN
IPATH=4		H_{min}

For all cases,

RADIUS -- earth radius,

H_{1C} -- altitude of the observer measured from the center of the earth ($H_{1C} = H_{1alt}$ + RADIUS), and

H_{2C} -- altitude of the source measured from the center of the earth (defined same as H_{1C}).

In IPATH=2, observer to source, different parameter sets are allowed. The process to determine the path will, therefore, vary. For example, in Case 1 the input variables include H_1, H_{2alt}, A_0, B_0 and LEN. Values for H_{min}, RANGE, and β are calculated. The angle γ, from which H_{min} and β are calculated, is given by

$$\sin\gamma = \frac{H_{1C}}{H_{2C}} \sin(\pi - A_0) \quad . \tag{9}$$

Then H_{min} and β are given by

$$H_{min} = H_{2C}\sin\gamma - \text{RADIUS} \quad , \text{and} \tag{10}$$

$$\beta = A_0 - \gamma \quad . \tag{11}$$

The range is easily obtained from

$$\text{RANGE} = \sqrt{H_{1C}^2 - H_{2C}^2 + 2H_{1C}H_{2C}(1-\cos\beta)} \quad . \tag{12}$$

When $H_{2C} < H_{1C}$, the two allowed downward paths are distinguished by LEN. The value of the angle γ determined using Equation (9) is always acute and corresponds to the longer path. For the shorter path, γ is replace by $\pi-\gamma$, and β and RANGE are determined as before from Equations (11) and (12). Cases 2, 3, and 4 are calculated similarly.

For case 5, input parameters include the latitude and longitude for the source and the observer. A_0, β, RANGE, and H_{min} are calculated. Using the given latitude and longitude, the angle β is given by

$$\cos\beta = \frac{X_1X_2 + Y_1Y_2 + Z_1Z_2}{H_{1C}H_{2C}} , \tag{13}$$

where

$$X = \rho\cos\Theta \sin\Phi ,$$
$$Y = \rho\sin\Theta \sin\Phi ,$$
$$Z = \rho\cos\Phi , \text{ and}$$

Φ is the latitude, Θ is the longitude, and ρ is H_{1C} or H_{2C}. RANGE, H_{min}, and A0 are determined as before.

When IPATH=3, the end point is space, so $H_{2alt} = H_{max}$, where H_{max} is the maximum altitude. Case 1 uses the same equations that are used for IPATH=2. Case 2 has two possible paths that are differentiated by LEN.

For IPATH=4, the latitude and longitude for both the observer and source are set to zero, and H_{1C} = RADIUS + H_{max}. The only input parameter is H_{min}.

5. THE CHEMICAL KINETIC MODULE

The CHEMKIN module computes the steady state number densities of vibrationally excited atmospheric species from a set of chemical kinetics/reaction mechanisms. CHEMKIN is user oriented and upgradable. The module is based on and includes sections of the Sandia Livermore CHEMKIN code,[3] which is described as "a general purpose, problem independent, transportable, FORTRAN chemical kinetics code." The Sandia CHEMKIN code is comprised of two major components, the interpreter and the gas phase subroutine library. The interpreter reads a symbolic description of an arbitrary chemical kinetics mechanism written just as it would be written by a chemical kineticist; it then translates this information into the appropriate differential rate equations. The output from the interpreter is a "linking" file that may be used by hundreds of subroutines in the gas phase library.

The SHARC CHEMKIN module uses a simplified interpreter, which does not contain information on elements, the thermodynamic data base, or reversible reactions. Although the code sets up the time-dependent differential rate equations, a steady state solution is currently used to obtain the vibrational state populations.

5.1 Structure of CHEMKIN

The CHEMKIN module consists of two independent codes, the interpreter and the routines to solve for the number densities of the vibrationally excited species. As mentioned above, the interpreter reads the chemical kinetics/reaction mechanism input file and then translates the input into a form usable by the chemical kinetic subroutines. A schematic illustrating the relationship of subroutines in the SHARC CHEMKIN module is shown in Figure 9.

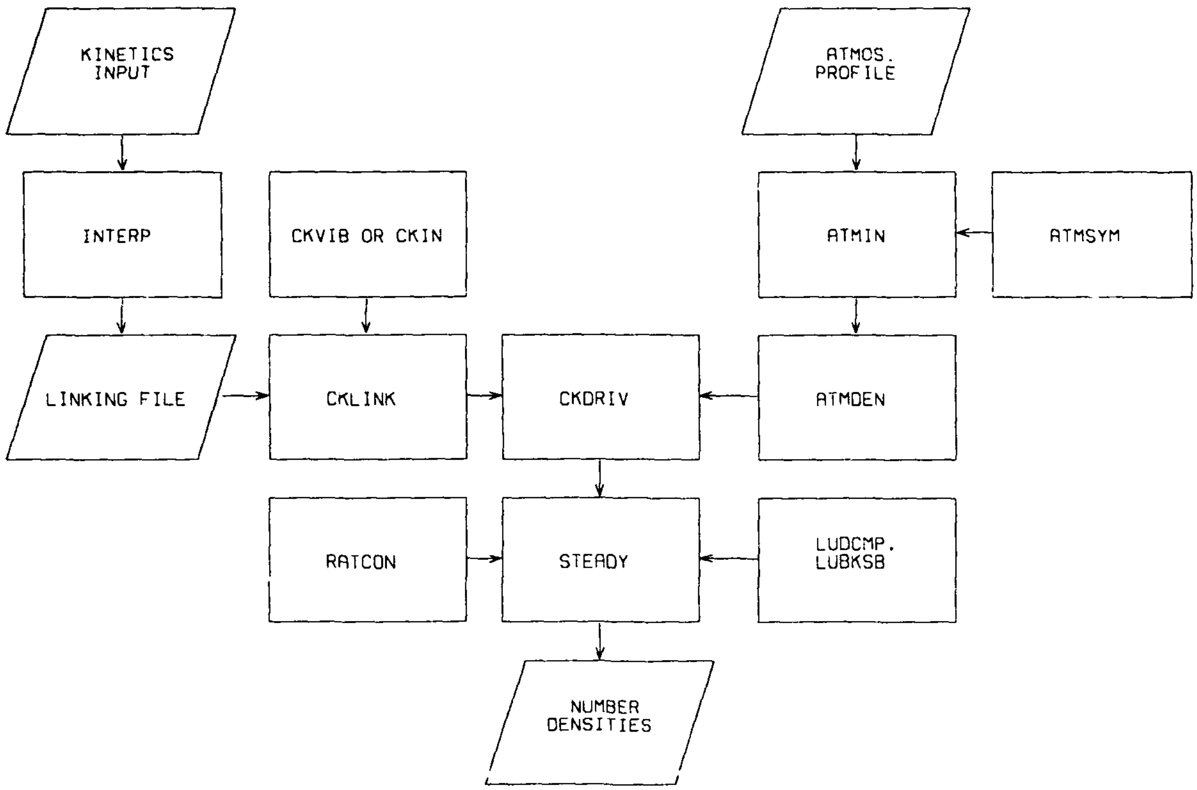


Figure 9. Schematic Showing the Relationship of the Subroutines Comprising the SHARC CHEMKIN Module.

5.2 CHEMKIN Validation

As an initial validation of the SHARC chemical kinetics package, the O_3 vibrational state number densities predicted by the steady state algorithm were compared with the steady state limit of a time dependent calculation. The time dependence of the O_3 excited state number densities is shown in Figure 10. The time dependent calculations were performed using a modified version of the Sandia CHEMKIN package. The agreement between the two methods is excellent in the steady state limit. Furthermore, the steady state SHARC CHEMKIN algorithm has been compared against simple analytical solutions to model rate schemes with exact agreement.

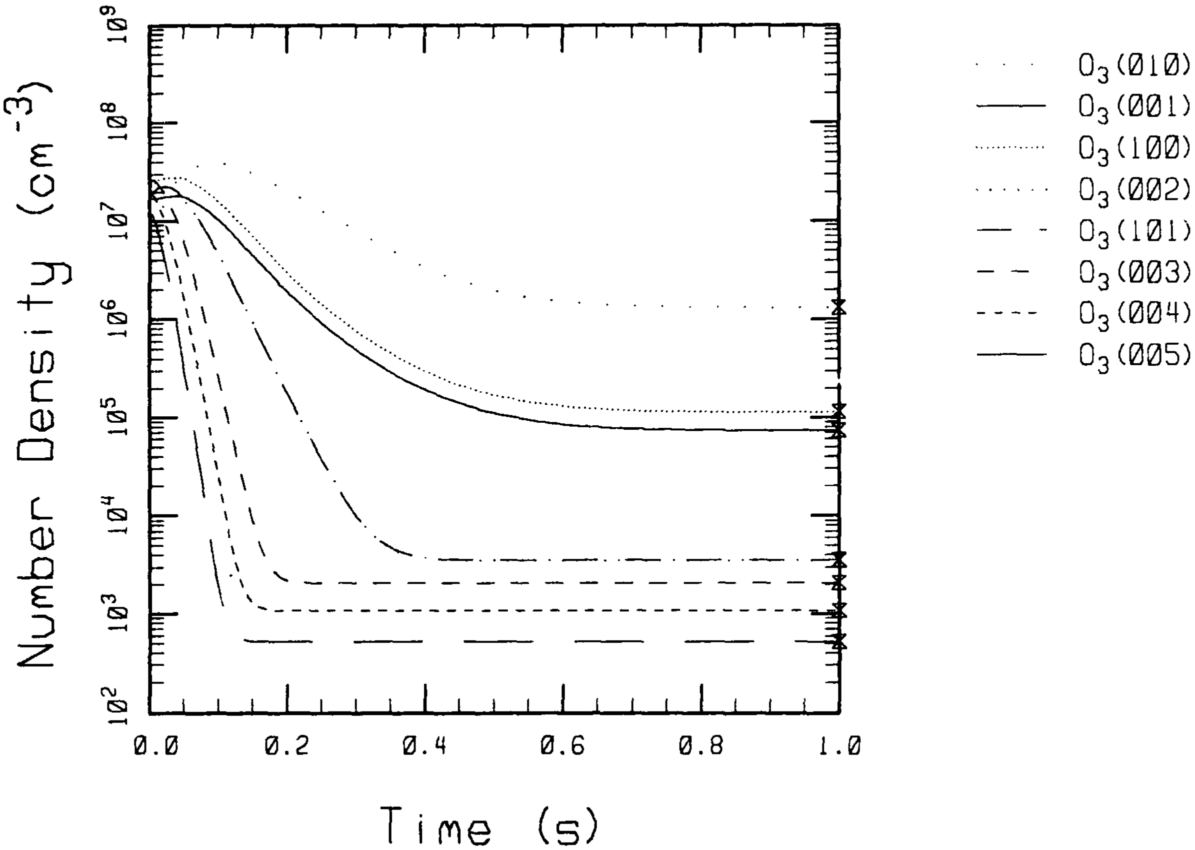


Figure 10. Time Dependence of the O_3 Number Densities at 80 km With Steady-State Calculations by SHARC CHEMKIN.

6. THE NEMESIS MODULE

Radiative excitation due to absorption of photons by atmospheric molecules is a significant NLTE process for many molecular bands. Some molecular bands (especially CO_2) are opaque in the upper atmosphere. A photon emitted by these strong bands will be absorbed and re-emitted many times before it either is collisionally quenched or escapes the atmosphere, resulting in enhancement of their upper state populations. In SHARC, this phenomenon is calculated by the NEMESIS module (Non-Equilibrium Molecular Emission and Scattering Intensity Subroutine).

Semi-infinite plane parallel geometry is assumed for the calculation of the enhanced excited state populations. Earth curvature effects are not important for this part of the calculation; however, they must be (and are) included when calculating the LOS radiances. The atmosphere is divided into a series of homogeneous layers. Two external sources of light are considered, upwelling earthshine from the lower atmosphere and downwelling sunshine. The earthshine is given a Lambertian angular distribution. Excited states are created by:

(1) Absorption of light via an effective rate constant which is the sum of the contributions from the two external light sources and

(2) Collision with, and energy transfer from, other excited molecules.

Excited states are destroyed by collisional quenching, energy transfer to other states, and radiative decay. NEMESIS calculates the steady-state excited state population distributions within the upper atmosphere (60 km and up) taking into account all of these processes.

The layer-to-layer radiative transfer model combines a Monte Carlo simulation for the first order emission-absorption probabilities between layers with an analytical formalism for all subsequent orders of emission-absorption. This basic approach involves two overall steps:

Step (1): Determine the steady state excited state population distributions resulting from just external illumination and collisional process, and

Step (2): Determine the enhancement of the Step (1) distributions due to internal layer emission and radiative trapping.

The separability of these steps is based on the assumption of weak coupling which means that the lower state populations are not significantly depleted due to the radiative trapping in Step (2).

In the Monte Carlo method, trial photons are started out from all sublayers, and their trajectories are followed until they exit the top or bottom of the entire atmospheric layer under consideration. Each absorption event contributes to the excited state population of the sublayer in which it occurs. The physical approximations used in this version of NEMESIS are:

- Semi-infinite plane parallel geometry;
- Translation-rotation temperature equilibration;
- Complete frequency redistribution across the line shape function after each absorption event;
- Complete rotational level redistribution after each absorption event;
- No overlap of absorption lines;
- Temperature independent radiative transfer; and
- Restriction to just the Doppler line shape.

These approximations correspond to those typically assumed in developing simplified analytical solutions to the problem and are identical to those used in the Degges model.[4] All of these approximations can be relaxed in the Monte Carlo approach; work is currently underway to remove the last two assumptions.

The probability of emitting at a particular line is proportional to the strength of that line. The HITRAN line strengths have been sorted into a number of bins ($\leq$ 10 for each molecular band). NEMESIS then picks its lines from a weighted average of the number of lines in each bin and their mean line strength. The exact frequency of an emitted photon is obtained by sampling from an appropriate Doppler profile.

These calculations for single photon exchange are used as inputs for calculating the higher order exchanges. The solution to this problem can be reduced to a system of linear equations of the form

$$\rho_{ui} = \rho_{ui}^{o} + \Omega_i \sum_j W_{ij}\rho_{uj} \quad , \tag{14}$$

where ρ_{ui} is the excited state number density in the upper "u" vibration-rotation manifold for the i'th atmospheric layer, ρ_{ui}^{o} is the source excited state density (calculated by CHEMKIN), Ω_i is the probability that a photon absorbed in the i'th layer produces an excited state, and W_{ij} is the average probability that a photon emitted from the j'th layer will be absorbed in the i'th layer (calculated by Monte Carlo). The source excited density ρ_{ui}^{o} corresponds to the solution of Equation (14) in the limit of no radiative excitation due to layer-layer emission-absorption events. Standard matrix methods are used to solve this linear equation system once the quantities ρ_{ui}^{o}, Ω_i, and W_{ij} have been defined. The ρ_{ui} are the predicted excited-state populations for each layer and are passed on to SPCRAD for the LOS radiance calculations.

7. THE SPCRAD MODULE

SPCRAD, the spectral radiance module calculates the radiance for the user's specified LOS path by numerically integrating the radiation transport equation along the LOS trajectory. It uses a numerical approach that represents a reasonable compromise between high spectral resolution (<0.1 cm^{-1}) calculations, which numerically integrate over each spectral line, and the lower resolution (usually ≥ 25 cm^{-1}) approaches of band models, which trade some (and sometimes considerable) accuracy for speed. In SPCRAD, the LOS radiance is calculated on a LBL-basis using an isolated-line, equivalent-width formulation. This technique is faster than numerical integrations over the entire line profile, as is done in standard LBL calculations, and it easily yields the present spectral resolution of 0.5 cm^{-1} and is extendable down to 0.1 cm^{-1} for altitudes above 50 km.

7.1 Structure of the Spectral Radiance Module

The spectral radiance calculation proceeds along the following basic steps:

(1) Read spectral line information for a single line from an augmented AFGL HITRAN line file.[6]

(2) Adjust the line strength and width to correspond to the kinetic, rotational, and vibrational temperatures in the (nth) atmospheric layer traversed by the LOS path.

(3) Calculate the path-averaged line strength and width using the Curtis-Godson approximation for the path from the observer through the nth layer.

(4) Determine the equivalent width of the line using the Voigt line shape and atmospheric parameters for this path.

(5) Calculate the line radiance contribution of the nth layer along the LOS.

(6) If all atmospheric layers along the LOS have been transversed, return to Step (1) or increment to the next atmospheric layer, n+1, and return to Step (2).

7.2 Equivalent Width of a Radiating Line

It is well known that the Doppler linewidth (*half width at half maximum*) is much larger than the Lorentz linewidth for altitudes above 50 km. However, much of the radiation from stronger bands which succeeds in escaping the atmosphere (or propagating a significant distance) tends to come from the far wings of the lines (which are Lorentzian). Thus a combined Doppler-Lorentz or Voigt lineshape function is required. A detailed calculation for the 15 μm CO_2 (ν_2) band with a Voigt lineshape demonstrated that the radiance was about four times that obtained when just a Doppler lineshape was used.[13] The atmospheric path was for limb viewing with a tangent altitude of 75 km.

The equivalent width, W, of a single isolated line is the ratio of the total radiance from that line to the blackbody radiance at the line center; in other words, it is the width of an equivalent line shape that is perfectly square with an emissivity of one and spectral width, W. The equivalent width is given by

$$W = \int_{-\infty}^{\infty} [\, 1 - e^{-P(\omega)X} \,] \, d(\omega) \quad , \tag{15}$$

where $P(\omega)$ is the Voigt lineshape function,[11,14] and X is the path length (or number of radiators in the column). There is no simple analytic form for W except for a pure Lorentz lineshape.

The Rodgers-Williams approximation[15] to the Voigt equivalent width

13. Bullitt, M. K., Bakshi, P. M., Picard, R. H., and Sharma, R. D., "Numerical and Analytical Study of High-Resolution Limb Spectral Radiance From Nonequilibrium Atmospheres," JQSRT, 34, 33 (1985).

14. Penner, S. S., *Quantitative Molecular Spectroscopy and Gas Emissivities*, Addison-Wesley Publishing Co., Inc., Reading, MA (1959).

15. Rodgers, C. D. and Williams, A. P., "Integrated Absorption of a Spectral Line with the Voigt Profile," JQSRT, 14, 319 (1974)

affords a reasonable compromise between computational efficiency and accuracy. It is given by

$$W_V = \alpha_D \sqrt{2/\ln 2} \sqrt{W_L^2 + W_D^2 - [W_L W_D / W_W]^2} \quad , \tag{16}$$

where the subscripts V,D,L,W refer to Voigt, Doppler, Lorentz, and weak-line limit, and α_D(cm^{-1}) is the Doppler linewidth. The individual equivalent width contributions are nondimensionalized by factoring out the term $\alpha_D \sqrt{2/\ln 2}$. The Doppler equivalent width is calculated using the approximation[11]

$$W_D = \sqrt{\ln(1+x^2)} \quad , \tag{17}$$

$$x = \sqrt{\pi/2}\,\tau_D \quad , \tag{18}$$

$$\tau_D = \frac{Su}{\alpha_D} \sqrt{\ln 2/\pi} \quad , \tag{19}$$

where τ_D is the optical depth at the line center, S(cm/molecule) is line strength, and u(molecules/cm^2) is absorber column density. The Lorentz equivalent width is approximated by[11]

$$W_L = \frac{x}{(1+c_o x/y)^{1/2}} \quad , \tag{20}$$

$$c_o = 1/(2\sqrt{2}) \quad , \text{ and} \tag{21}$$

$$y = \sqrt{\ln 2}\, \frac{\alpha_L}{\alpha_D} \quad , \tag{22}$$

where α_L(cm^{-1}) is the Lorentz linewidth. The weak-line limit is given by

$$W_W = x \quad . \tag{23}$$

The peak error of 10 percent from this approach is comparable to the 8 percent peak error in using the approximations for W_D and W_L. However, the above expressions for W_D and W_L are calculated more quickly than the more accurate polynomial series developed by Rodgers and Williams.

To simplify the equivalent width evaluation for an inhomogeneous path, such as for the multi-segmented atmospheric los, the Curtis-Godson approximation[11] is used to define a path-averaged homogeneous path. The effective single path quantities are given by

$$Su = \sum_{i=1}^{i} S_i u_i \quad , \text{ and} \tag{24}$$

$$\alpha = \frac{1}{Su} \sum_{i=1}^{i} S_i u_i \alpha_i \quad , \tag{25}$$

where α refers to α_D and α_L, and the summation upper limit, i, denotes that the equivalent width, W_i, is defined for the path from the observer to the beginning of the i'th segment.

For the path radiance calculation, the LOS through the atmosphere is represented by *a number of homogeneous segments. For each emission line the* LOS spectral radiance for a path traversing imax homogeneous layers is given by[11]

$$I = \sum_{i=1}^{i_{max}} R_i (W_{i+1} - W_i) \quad , \tag{26}$$

where R_i is the emission source function ($w/cm^2/sr/cm^{-1}$) for the i'th segment, and W_i is he equivalent width for the path from the observer to the start of the i'th segment. This representation is valid for both the LTE and NLTE limits.

7.3 Illustrative Calculations of Line Radiance

In this subsection we present some calculations for the 4.67 μm band of CO. The SPCRAD calculations are compared against results from an LBL model, dubbed NICE, which was developed at Spectral Sciences to study high spectral resolution NLTE emission from rocket plumes. NICE provides a good test for

SPCRAD since it directly integrates over a Voigt line shape and uses the AFGL Atmospheric Absorption Line Database. Two geometries were used for the test calculations. They feature an observer at 60.1 km looking vertically up to either 62 km or 80 km. In the first scenario the path length is 1.9 km, and only one atmospheric layer is sampled. In the second case, the path length is 19.9 km, and ten atmospheric layers are sampled.

A representative CO line with the following properties was used:

ω_o	2131.632 cm^{-1}
SR*	8.049874E-17 cm^{-1}/molecule/cm^{-2}
GAM	0.08 cm^{-1}
E"	23.07 cm^{-1}
EVIB	0.0 cm^{-1}
EROT	23.07 cm^{-1}
IMOL	5
ISO	1
IUP	2
ILOW	1

The radiance calculated for the 1.9 km path by SPCRAD was 1.7594 x 10^{-12} W/sr/cm^{-2}, and NICE calculated 1.7550 x 10^{-12} W/sr/cm^2. The difference between the two calculations is only 0.25%. This is excellent agreement and is much less than uncertainties in other SPCRAD parameters, such as excited state populations and atmospheric profiles. An LOS with multiple layers puts more stress on SPCRAD by testing the Curtis-Godson approximation and the finite difference formula, Equations (25) and (28). When the 19.9 km path is used, SPCRAD calculates 8.105x10^{-12} W/sr/cm^2, while NICE calculates 7.890x10^{-12} W/sr/cm^2. The results differ by about 2.7%. This is more typical of the expected accuracy of our approach.

Figure 11 shows the spectral radiances calculated by NICE for both the 1.9 and 19.9 km paths. The NICE integration over the line shape was performed in steps of 0.0005 cm^{-1} resolution to insure that the line shape was properly traced. Both of the paths lead to an emission feature which is non-Doppler in shape, even though the Doppler line width was 100 times larger than the Lorentz (2.2×10^{-3} vs 1.46×10^{-5} cm^{-1}). The emission from the single line is nearly optically thin, so most of the fall-off seen in Figure 11 is due to the decrease in CO population with altitude and not to attenuation of emission by the various atmospheric layers when transmitted down to the observer.

Figure 12 shows the radiance reaching the observer from each of the ten layers. The agreement between the codes is good, with the small disagreement becoming worse as layers get further away from the observer. Overall, these single line calculations demonstrate good agreement between SPCRAD and an "exact" LBL calculation.

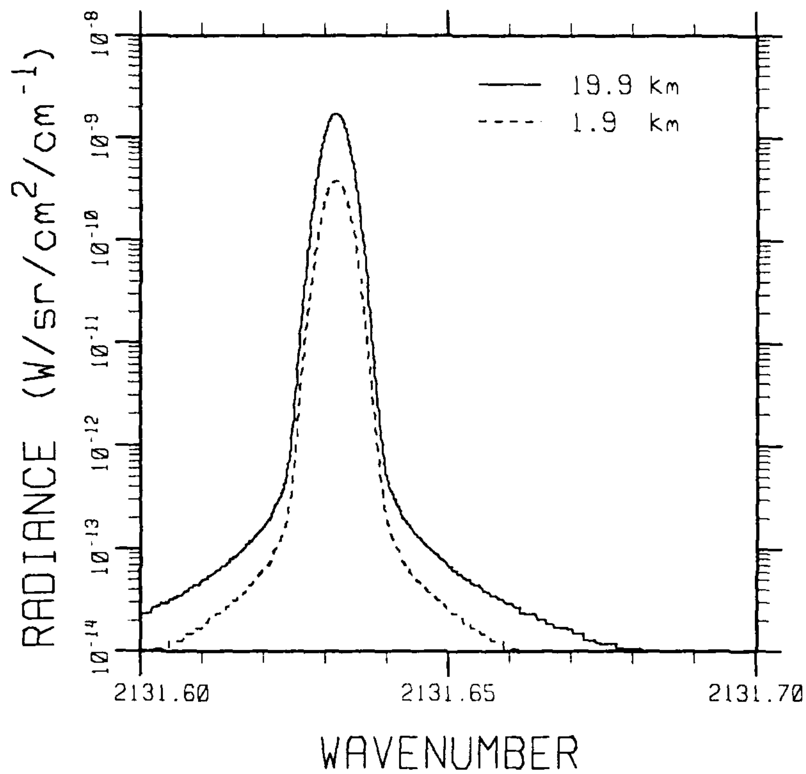


Figure 11. Spectral Radiance for Single CO Line for a Vertical Path from 60.1 to 62 km (Dashed Line) and 60.1 to 80 km (Solid Line).

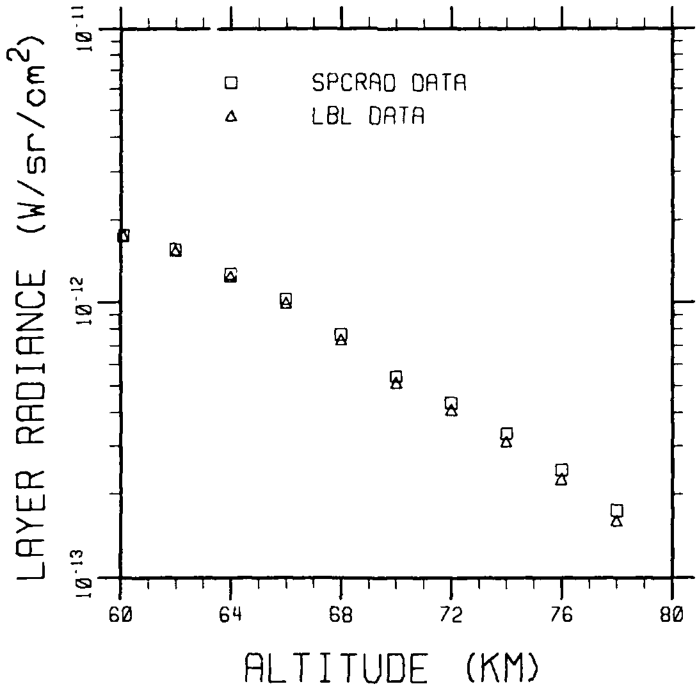


Figure 12. Comparison Between SPCRAD (Boxes) and NICE (Triangle) Calculations for the Radiance Reaching the Observer at 60.1 km from Higher Altitudes.

8. ILLUSTRATIVE CALCULATIONS

Some illustrative SHARC calculations of atmospheric radiance are presented for typical high-altitude paths. The calculations illustrate the expected range of atmospheric radiation for different day/night conditions, path trajectories and model atmospheres.

Figure 13 shows the daytime limb radiance for three different atmospheric paths. The same three cases under nighttime conditions are shown in Figure 14. The observer is in space and looking at the earth limb along tangent paths whose minimum altitudes are 60, 90 and 120 km. The different altitudes are easily distinguished as the intensity of the radiance decreases with increasing altitude. The U.S. Standard Atmosphere was used to define the vertical profile of pressure, temperature and species number density. The calculations were done at a spectral resolution of 0.5 cm^{-1} and degraded to 10 cm^{-1} for these and the two subsequent figures. The molecular species generating the stronger peaks are indicated in the figures. The strongest daytime bands are the $CO_2(\nu_3)$ at 4.3 μm, the $O_3(\nu_3)$ at 9.3 μm and the $CO_2(\nu_2)$ at 15 μm. The optical opacity of the 2.7 and 4.3 μm CO_2 bands is seen in the very slight decrease between 60 and 90 km. The decrease between 90 and 120 km is much larger because they are no longer opaque. Similar arguments also apply to the 9.3 μm O_3 and the 15 μm CO_2 bands.

Comparisons of the day and night radiances are shown in Figures 15 and 16 for limb altitudes of 60 and 120 km, respectively. The major differences are the decrease in the nighttime radiance in the bands at wavelengths shorter than 4.5 μm. This is due to the lack of solar energy for creating significant NLTE populations in the higher vibrational states of these bands. The decrease in the 4.3 μm CO_2 band is most dramatic; its daytime radiance is much stronger than expected because the NLTE states excited by solar pumping of the shorter-wavelength bands have significant decay channels via transitions in the 4.3 μm band.[9] The NO band at 5.3 μm is unchanged by diurnal variations. Highly excited NLTE $O_3(\nu_3)$ vibrational transitions are responsible for the radiance on the long-wavelength side of the band center at 9.3 μm.

Figure 17 shows three slant paths to space from an altitude of 60 km, for zenith angles of 0, 60 and 90°. The spectral resolution has been reduced to 20 cm^{-1} for clarity. The differences in radiance are mostly due to the larger optical depth at larger zenith angles.

The four model atmospheres shown in the calculation for Figure 18 are the U. S. Standard, 15° Annual, 30° Winter and 60° Winter for an exoatmospheric temperature of 1000 K. The angles refer to the latitude (North) of the model profiles. These profiles and others are resident in SHARC (see Section 4.). The radiance is for a 90 km limb path, and the spectral resolution is 20 cm^{-1}.

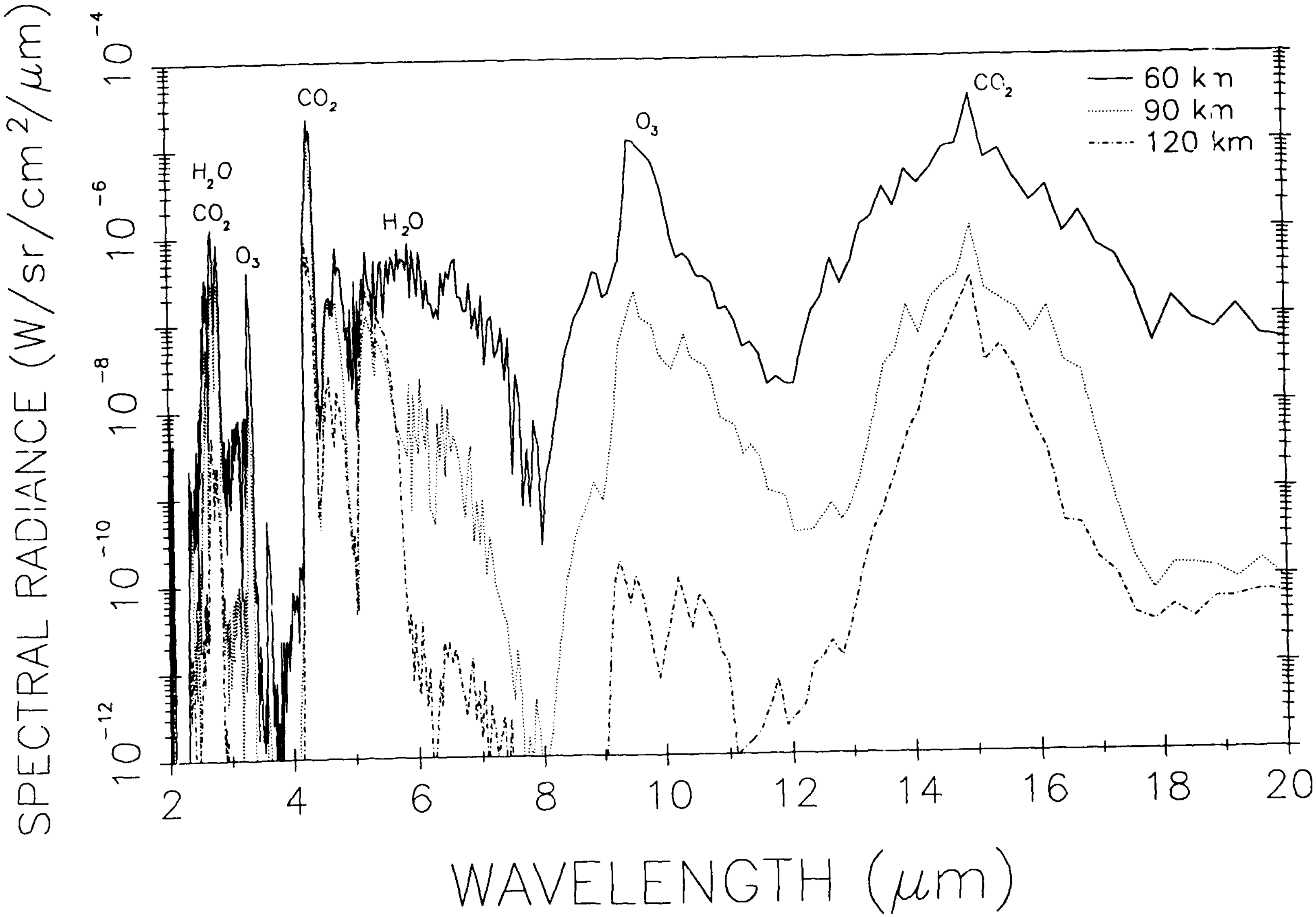


Figure 13. SHARC Calculation Under Daytime Conditions for Three Limb Viewing Paths at Tangent Altitudes of 60, 90 and 120 km Altitude.

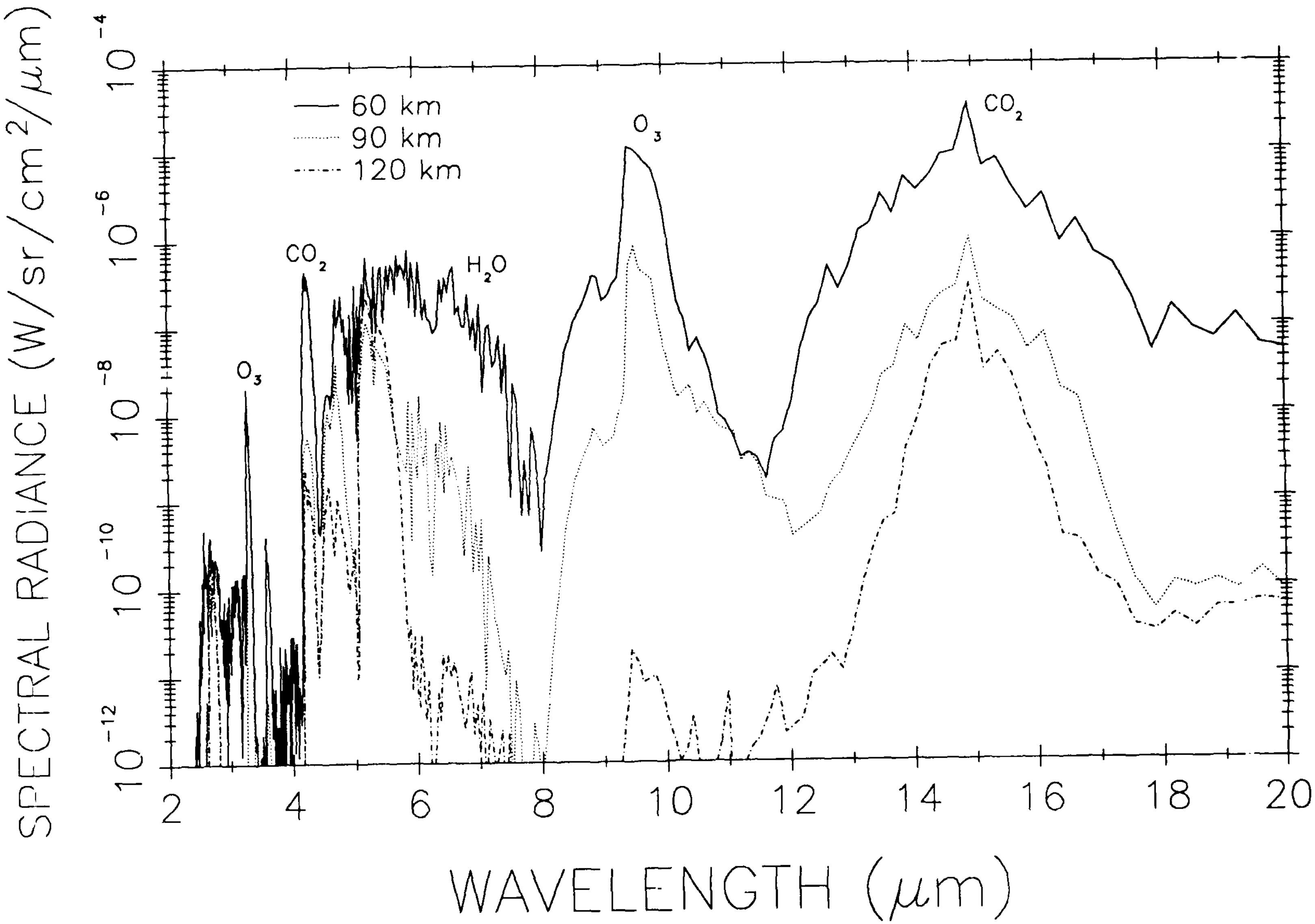


Figure 14. SHARC Calculation Under Nighttime Conditions for Three Limb Viewing Paths at Tangent Altitudes of 60, 90 and 120 km Altitude.

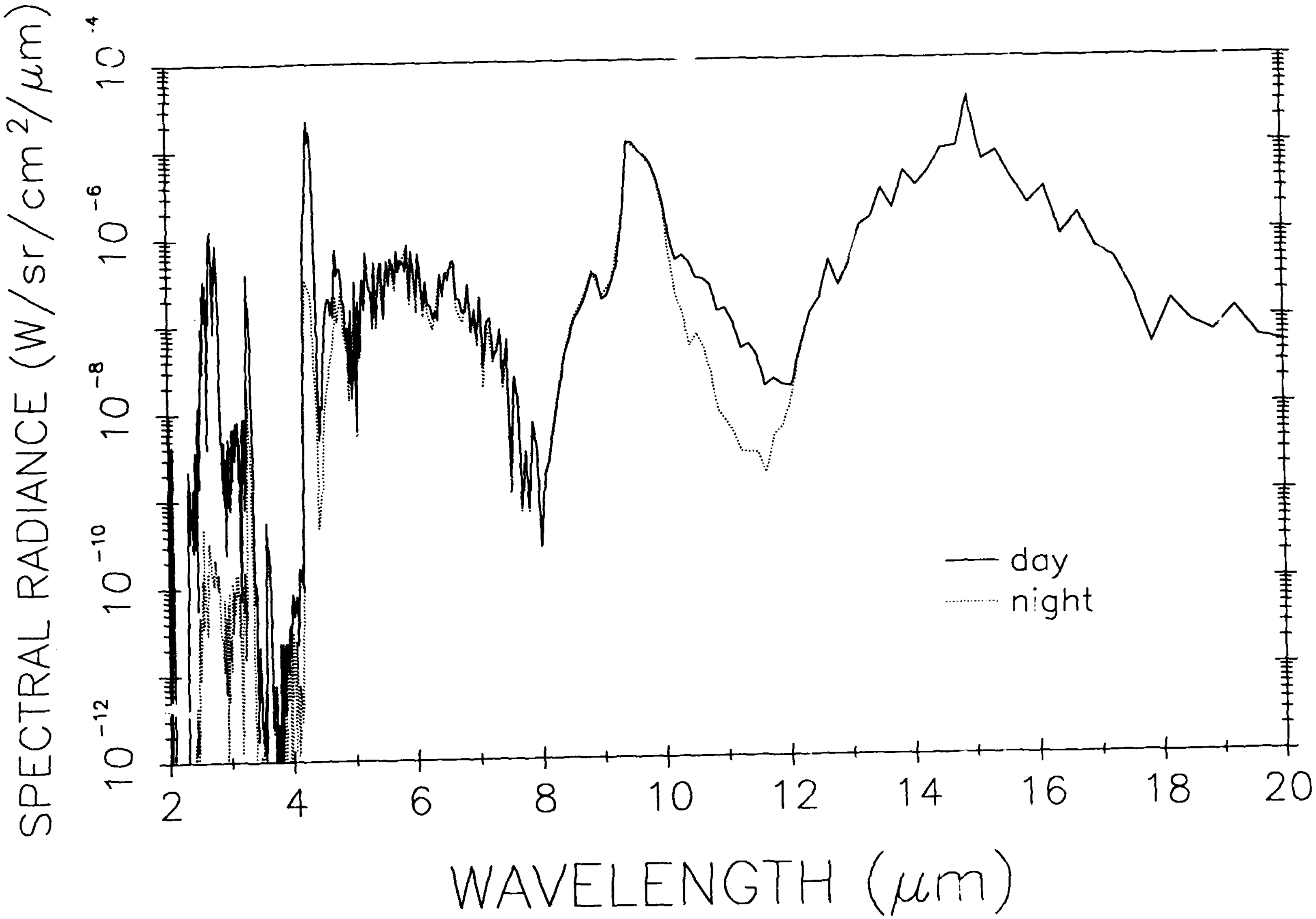


Figure 15. Comparison of Daytime and Nighttime Radiances for Limb Viewing at 60 km Altitude.

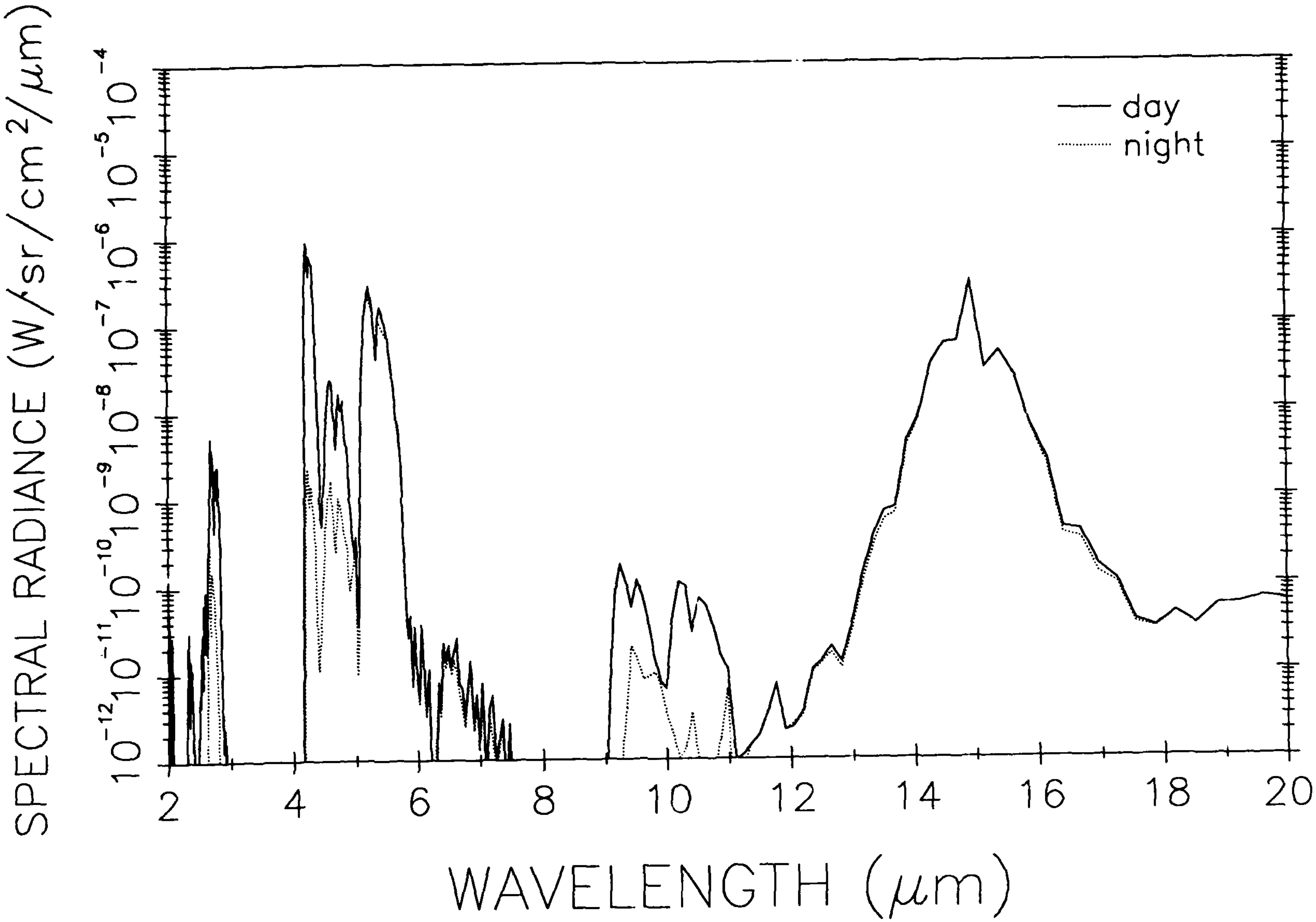


Figure 16. Comparison of Daytime and Nighttime Radiances for Limb Viewing at 120 km Altitude.

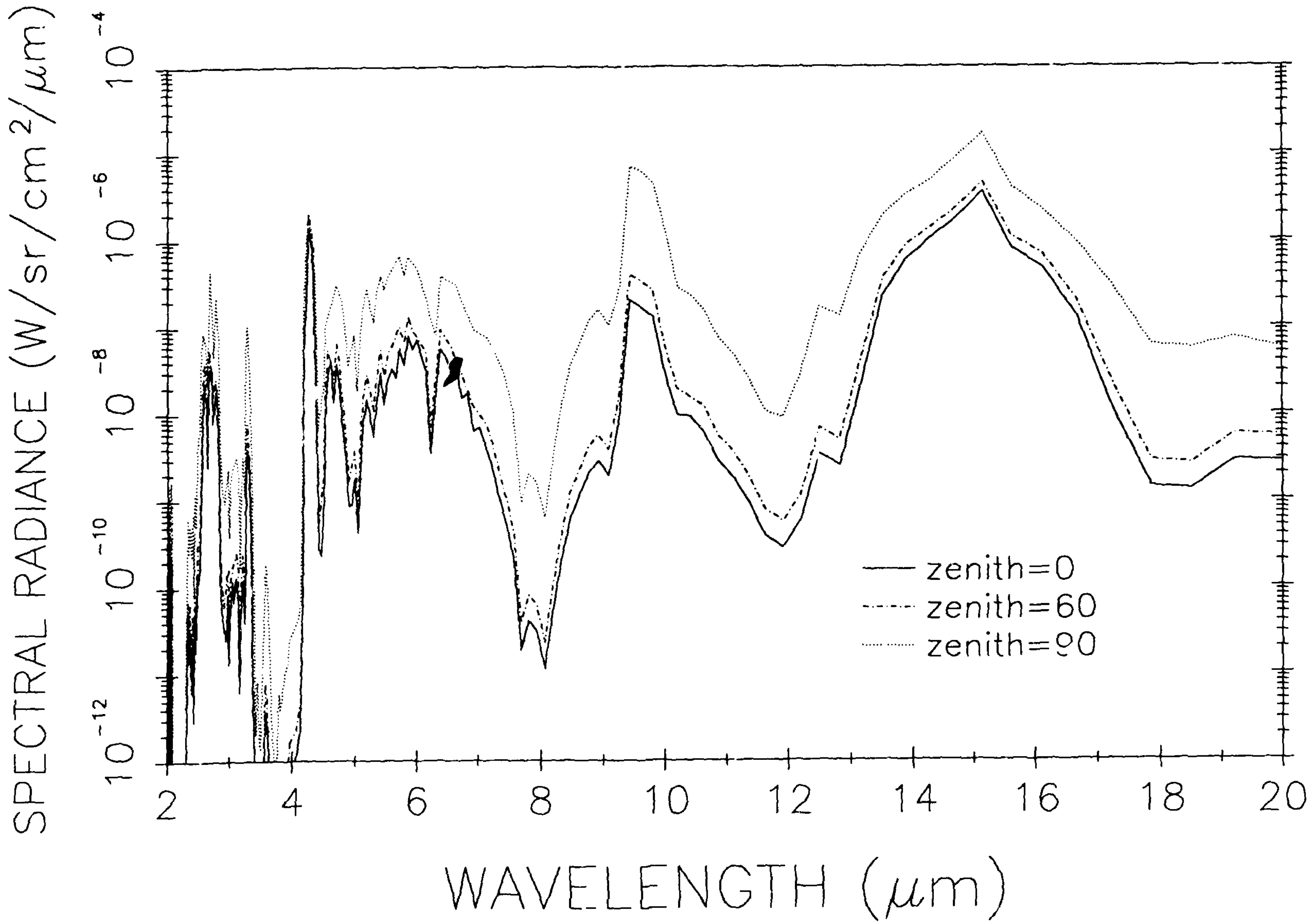


Figure 17. Atmospheric Radiance for a Slant Path to Space From 60 km Altitude and for Zenith Angles of 0, 60 and 90°.

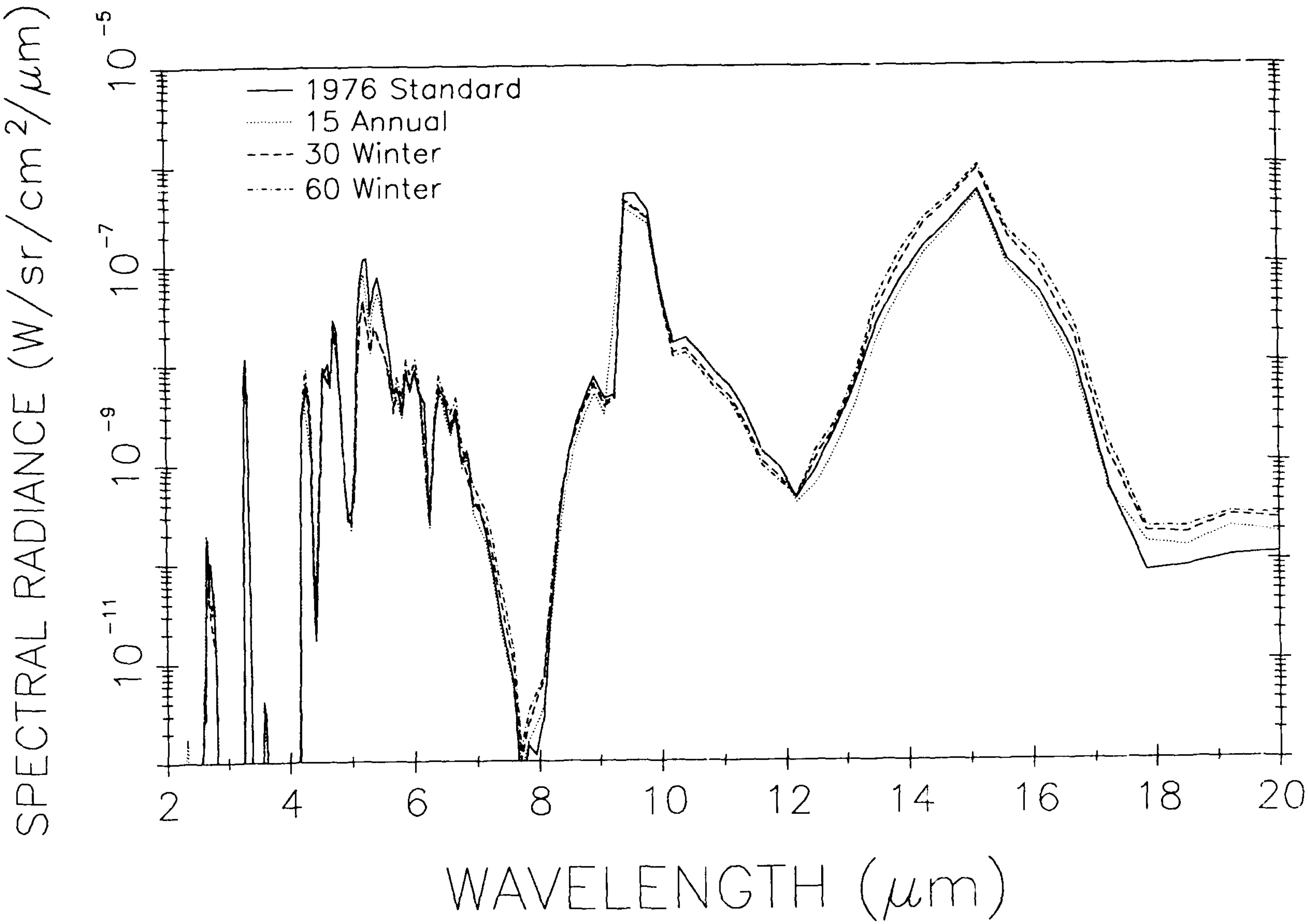


Figure 18. Atmospheric Radiance for a 90 km Limb Viewing Path as Calculated for Four Different Atmospheric Profiles, the 1976 U. S. Standard, the 15° Latitude Annual, the 30 and 60° Latitude Winter.

9. CONCLUSION

This report has introduced the first version of SHARC, the Strategic High Altitude Radiance Code. It calculates high-altitude, NLTE radiance and transmittance for paths between 60 and 300 km (including space viewing), within the 2-40 μm spectral region, with a resolution of 0.5 cm^{-1}, and for arbitrary paths such as limb, horizontal, vertical, or slant. Radiation is calculated for the five molecules most important at these altitudes: CO_2, O_3, NO, H_2O, and CO. When combined with the SHARC Users Manual, which is reproduced in the appendix, sufficient information is available for applying the code to problems involving atmospheric IR radiance between 60 and 300 km altitude.

The authors would appreciate receiving information about problems, applications and general comments about the code's use. Several upgrades are planned or are underway. Some concluding comments about the upgrades and the status of the present model are:

- Isotopes: Isotopes of the major species will be added during FY90. This is particularly important for CO_2 radiation in the 4.4-4.9 μm spectral region when the code is extended down to lower altitudes.

- Auroral Model: An auroral capability based on the AARC (Auroral Atmospheric Radiation Code) developed at GL[16] is being developed for SHARC. This module is almost completed and will be available in May, 1990.

- Validation: Data analysis and model validation is an ongoing GL effort which is especially applicable to SHARC. The code is only as good as the data on which the models are based. Therefore new

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16. Winick, J. P., Picard, R. H., Joseph, R. A., Sharma, R. D., and Wintersteiner, P. P., AARC: The Auroral Atmospheric Radiance Code," AFGL-TR-87-0334 (November 1987). AD A202432

experiments and analyses of presently available data are an ongoing effort. Program schedule requirements to get SHARC developed and distributed has forced compromises in the validation and upgrade part of the code. It is through codes like SHARC that the knowledge gained from field experiments is transferred to systems users and development.

- Extend to 50 km Altitude: Work is presently underway to extend the code down to 50 km altitude. It will be completed during FY90.

- Additional Radiators: Additional radiators like OH, $O_2(^1\Delta)$ and other SWIR bands can be incorporated. A module for OH is scheduled for next fiscal year. We plan to upgrade the model for N_2^*-$CO_2(\nu_3)$ coupling during FY90.

- Data Base Upgrade: Analysis of the data from the GL SPIRIT I experiment indicates that the present estimates for the strength and location of the various $O_3(\nu_3)$ hot bands around the 10-11 μm spectral region need updating. This is scheduled to be done during the next fiscal year.

- Atmospheric Profiles: The profiles presently in SHARC have been taken from the AFGL HAIRM Code[4] and need to be reviewed and updated.

- H_2O Rotational Bands: The predicted radiation for the 16-25 μm region seems to be a little high for altitudes above 100 km. The present model seems reasonable at lower altitudes, and the water vapor profile for higher altitudes may be too high. Unfortunately, we know of no data for this spectral region.

- Spatial Structure: The SHARC framework can be adapted to include a model for clutter or spatial fluctuations. As this is an important consideration for surveillance and targeting systems, intensive effort in development is recommended.

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APPENDIX

THE STRATEGIC
HIGH-ALTITUDE ATMOSPHERIC RADIATION CODE
(S H A R C)
USER INSTRUCTIONS

TABLE OF CONTENTS

APPENDICES

1. INTRODUCTION

This user's manual for the Strategic High-altitude Atmospheric Radiation Code (SHARC) presents both an overview of the modeling approach as well as detailed code implementation and running instructions. SHARC predicts infrared (IR) atmospheric radiation and transmittance in the 2-40 μm spectral region at a spectral resolution of 0.5 cm^{-1} and includes the important bands of NO, CO, H_2O, O_3, and CO_2. It allows for arbitrary paths within the 60 to 300 km altitude region, such as limb, horizontal, vertical, slant, point-to-point, and space-viewing geometries. A full technical discussion of the modeling approach will be provided.

Generally above an altitude of 60 km collisional excitation and de-excitation processes between molecules occur on a time scale comparable to radiative decay. This leads to a condition of Non-Local Thermodynamic Equilibrium (NLTE) where the various degrees of vibrational, rotational, and translational freedom cannot be characterized by a single temperature. In this regime the concept of temperature, which implies a Boltzman distribution of excited-state populations, is invalid, and the explicit molecular excited-state populations need to be determined. In order to compute these populations, a comprehensive model is required which incorporates all the important physical processes which for this problem include: (1) collisional excitation, de-excitation, and energy transfer; (2) chemical production of excited-state molecules; (3) radiative decay; (4) external source excitation due to solar and earthshine pumping; and (5) internal radiative excitation due to emission and absorption by molecules within the atmosphere. All these effects are incorporated in SHARC.

SHARC is a completely new code which emphasizes modular construction so that models and model parameters can be easily modified or upgraded as additional data and/or better models become available. The present modules include input, chemistry, radiative transport, geometry, and output. The input module is interactive and menu-driven. It reads in the model atmosphere and prepares inputs for the rest of the code. The next step is calculation of the excited-state populations. This is accomplished in the chemistry module which iterates between a generalized chemical kinetics module that calculates excited-state populations due to solar and earthshine excitation and a Monte-Carlo based radiative transfer model that calculates radiative excitation and energy transfer between atmospheric layers. The geometry module determines the species column densities for each layer traversed by the user's requested path. The radiative transport module then calculates the radiance along the path for each molecular excited state. The calculation is done on a line-by-line basis in that the total radiation from each line is calculated using a single-line equivalent-width formulation that incorporates a Doppler-Lorentz (Voigt) lineshape.(1) Finally the results are passed to a separate plotting package which prepares a spectral plot of the calculated radiance.

Additional upgrades to SHARC are planned. These include an auroral model which is based on AARC (Auroral Atmospheric Radiation Code),(2) inclusion of isotopes of primary molecules, especially $^{13}CO_2$, additional radiators, such as OH and O_2 bands, extension down to 50 km altitude, and a model for lines of sight that cross the day-night terminator.

2. PROGRAM OVERVIEW

There are three major components of the overall SHARC software package, and these are indicated in Figure 1. The INTERPRETER, which is a modified version of that furnished with the Sandia CHEMKIN code,[3] prepares the differential equations for the chemical/kinetic reaction scheme. This module is run only when changes are made to the reaction scheme or its associated rate constants. The SHARC chemistry/radiation module is composed of many sub-modules, each of which models a specific physical process. This module utilizes the differential equations set up by the INTERPRETER and associated atmospheric and spectroscopic data to determine spectral radiances for arbitrary spectral regions, molecular emitters, and viewing geometries. Finally, a PLOTTING package is provided which allows the user considerable flexibility to vary the display format of the spectral radiance plots. The functions of each of these modules are described in the following sections.

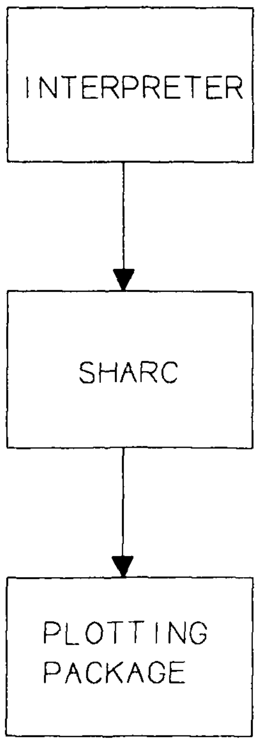

Figure 1. Major Components of SHARC.

2.1 The INTERPRETER Program

The SHARC CHEMKIN module computes the steady-state number densities of vibrationally excited atmospheric species from a set of chemical kinetics/reaction mechanisms. The chemical kinetics mechanism describes molecular formation, all forms of vibrational energy transfer, and the absorption of solar and/or earthshine radiation. SHARC's access to the chemical kinetics mechanism and associated input (i.e., energy transfer or reaction rate constants) is provided by a program called the INTERPRETER. The INTERPRETER reads a symbolic description of an arbitrary chemical kinetics mechanism (written in a manner just as a chemical kineticist would write it), and creates a binary "linking" file which contains all of the kinetics information. The SHARC INTERPRETER is based entirely on and includes subroutines directly from the Sandia Livermore INTERPRETER code which is provided with the CHEMKIN code.[3] The Sandia CHEMKIN package is described as "a general-purpose, problem-independent, transportable, FORTRAN chemical kinetics code."[3] The SHARC INTERPRETER is a modified Sandia interpreter from which information on elements in the periodic table, the thermodynamic data base (useful for combustion reactions), and reversible reactions, extraneous for our application, has been removed.

Once the chemical kinetics mechanism has been formulated, the INTERPRETER provides the vehicle by which the information is transferred to the CHEMKIN module in SHARC. The INTERPRETER reads a symbolic description of an arbitrary chemical kinetics mechanism in a manner that is just as would be written by a chemical kineticist; it then translates this information into the appropriate differential rate equations. To be more specific, consider I irreversible kinetic (energy transfer or reactive) processes, each given in the general form

$$\sum_{k=1}^{K} \nu_{ki} C_k \xrightarrow{k_i} \sum_{k=1}^{K} \nu'_{ki} C_k \quad , \tag{1}$$

where the stoichiometric coefficients ν_{ki} are integers; the C_k is the chemical symbol for the k^{th} species; and k_i is the rate constant for the ith process. The INTERPRETER reads this symbolic description of an arbitrary chemical kinetics mechanism and provides the data necessary to translate the mechanism into the appropriate differential equations

$$\frac{dw}{dt} = \sum_{i=1}^{I} (\nu'_{ki} - \nu_{ki}) k_i \prod_{k=1}^{K} [C_k]^{\nu_{ki}} \quad . \qquad (2)$$

All the variables defined in Equations (1) and (2) are written into a binary "linking" file. The INTERPRETER only has to be run once for a given kinetics mechanism and data base. The "linking" file is then saved and used by SHARC for all subsequent calculations. Of course, if the kinetics mechanism or data base is changed, the INTERPRETER has to be rerun.

2.2 SHARC

The schematic shown in Figure 2 illustrates the calculational sequence for SHARC. Except for the PLOTTING and the INTERPRETER modules, which are run separately, all the modules are called by the MAIN program.

The interactive input module queries the user for the parameters needed by the rest of the code. The MAIN program reads in the appropriate atmospheric profile and determines the temperature, pressure, and species concentration for each layer.

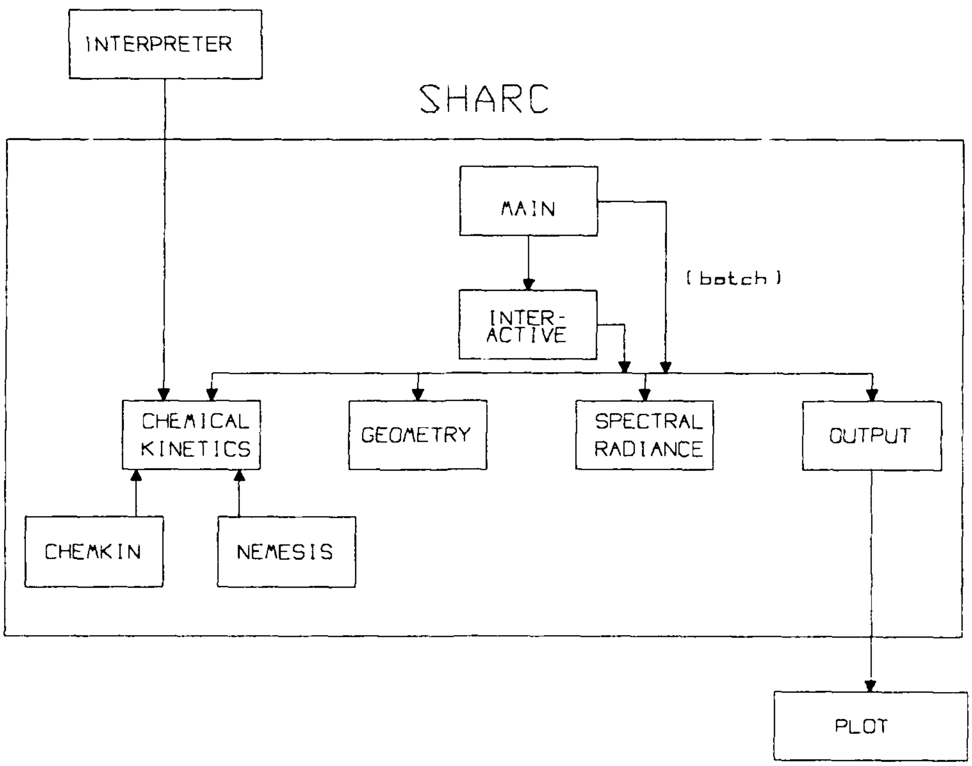

Figure 2. Calculational Sequence for SHARC.

The atmospheric chemistry modules, CHEMKIN and NEMESIS, calculate the NLTE populations for the various molecular excited and ground states. CHEMKIN calculates excitation due to chemical reactions plus solar and earthshine pumping. NEMESIS then calculates changes in the excited-state populations due to radiative transfer between molecules within the atmosphere.

The GEOMETRY module determines the line-of-sight (LOS) trajectory parameters for the viewing geometry requested by the user. It uses the density profiles calculated by CHEMKIN-NEMESIS to determine the LOS column densities for each excited state. Arbitrary paths between 60 and 300 km are allowed, including limb viewing from space, vertical and horizontal paths, and slant paths of arbitrary length and direction.

The SPCRAD module utilizes the geometry information provided by GEOMETRY and the state populations provided by CHEMKIN-NEMESIS along with a molecular spectroscopic data base to determine the LOS spectral radiance.

2.2.1 The INPUT Module

The INPUT module is used to interactively change input parameters required for a SHARC calculation. This module is used only when SHARC is run interactively. When SHARC is used in the batch or background mode, a previously created input file must be used. In the interactive execution mode, SHARC will look for the input file called "SHARC.INP". This file contains the user-supplied input parameters for SHARC (several of these files are supplied on the SHARC computer tape and discussed in the test case section of this manual). If "SHARC.INP" is not found, the input module will use a set of default values for all input parameters. Once SHARC has a set of input parameters, the input module displays the top-level input menu. The query-style menus used in the input module were modeled after the input menus used in the AFGL Auroral Atmospheric Radiance Code (AARC).(2) The top-level menu looks like this:

```
REVIEW OR MODIFY INPUT PARAMETERS

1. TITLE FOR CALCULATION*
2. MODEL ATMOSPHERE
3. NEMESIS CONTROL PARAMETERS
4. MOLECULAR EMITTERS*
5. SOLAR ZENITH ANGLE
```

6. POPULATION FILE*
7. LOS GEOMETRY*
8. SPECTRAL INTERVAL AND RESOLUTION*
9. OUTPUT DATA*

* OPTIONS CAN BE CHANGED WHILE USING OLD POPULATION FILES

10. UPDATE DEFAULT FILE AND EXIT FOR BATCH EXECUTION
11. EXIT WITH NO UPDATE OF DEFAULT FILE

ENTER # OF ITEM TO BE CHANGED
0 TO CONTINUE SHARC EXECUTION

The user can enter a number from 1 to 9 to enter a submenu on topics 1 through 9. The submenu will start by reviewing the current parameter values found in SHARC.INP, and the user can then select a parameter to be changed. The value is then changed simply by typing in the new value and then entering a 0 will return the user to the submenu level. Entering another 0 will return the user to the main menu. At this stage the user can enter another submenu by inputing a value from 1 to 9 or, by entering a value of 10, the user can exit the input menu and update the "SHARC.INP" file for a batch calculation. Entering an 11 will exit the SHARC calculation without changing the "SHARC.INP" file (used to quit SHARC when many input parameters have been incorrectly entered), and entering a 0 will allow SHARC to continue interactive execution. A more complete example of an interactive input session is described in Section 4.2.

Changes made to input parameters will be saved in the "SHARC.INP" file. The first parameter in "SHARC.INP" determines whether SHARC is to be run in an interactive or batch/background mode. When this parameter is a 1, SHARC will run interactively and enter into the input module. When this parameter is 0, SHARC will execute in a batch or background mode and skip the input module. This parameter is set to a value 1 after complete execution of SHARC so that the default mode for SHARC is the interactive mode. If a batch run is desired, this parameter can be changed by editing the "SHARC.INP" file, or one can exit SHARC with option 10 which prepares "SHARC.INP" for batch execution, i.e., the mode parameter is set to 0.

2.2.2 The CHEMKIN Module

The CHEMKIN module computes the steady-state number densities of vibrationally excited atmospheric species from a set of chemical kinetics/reaction mechanisms for each atmospheric layer. Again the subroutines comprising the CHEMKIN module are based on those included in the Sandia Livermore CHEMKIN package.[3]

The CHEMKIN module uses the input read from the "linking" file (species identification, stoichiometric coefficients, and rate constant parameters) to construct the steady state equations for the vibrationally excited states

$$\sum_{i=1}^{I} (\nu'_{ki} - \nu_{ki}) k_i \prod_{k=1}^{K} [C_k]^{\nu_{ki}} = 0 \quad . \qquad (3)$$

The variable definitions are identical to those defined in Equation (2). In general, solving Equation (3) for the vibrationally excited-state densities requires a nonlinear equation algorithm. However, using the assumption that the ν_{ki} of the vibrationally excited species (i.e., the unknowns in the problem) are unity, Equation (3) simply reduces to a set of linearly independent algebraic equations for the N unknown excited-state number densities. This assumption is not overly restrictive and has been used previously.[4] The information necessary to solve Equation (3) is simply the atmospheric species number densities and the kinetic temperature from which the rate constants are computed. SHARC then uses a lower/upper (LU) decomposition algorithm to solve Equation (3) for the number densities.

2.2.3 The NEMESIS Module

The NEMESIS (Non-Equilibrium Molecular Emission and Scattering Intensity Subroutine) module computes the enhancement of the atmospheric excited-state layer populations due to layer radiative self-trapping and layer-layer radiative pumping. Some molecular bands, in particular the 4.3μm CO_2 band, are optically opaque to emitted radiation. Photons emitted in these bands may be absorbed and emitted many times before either escaping the atmosphere or becoming collisionally quenched.

The overall approach for determining the enhanced excited-state level populations involves:

- determination of the steady-state layer source populations which includes excitation by external light sources, sun and earthshine, and molecular collisions, and de-excitation by radiative decay and collisional quenching;

- determinat... of the first-order population enhancement using a Monte Carlo simulation of the initial source photon emissions and their subsequent absorption or escape; and

- determination of the total enhanced populations using a recursive orders-of-enhancement approximation which is initialized by the Monte Carlo first-order results.

The source populations include all sources of excitation exclusive of the internal atmospheric radiative effects of layer self-trapping and layer-layer pumping. CHEMKIN is used to generate the source populations that are then input into NEMESIS. The key results from the Monte Carlo simulation are the first-order enhancements and the probabilities that a photon emitted from a layer "i" will create a new excited-state in a layer "j". This simulation involves sampling over the initial emission position, emission direction, emission frequency, emission line strength, and length of travel. The contribution of each succeeding order-of-enhancement is determined recursively by

$$(P_k) = (P_{k-1})(W) \quad , \qquad (4)$$

where (P_k) is the kth-order layer population enhancement matrix, and (W) is the layer-layer absorption probability matrix. Both (P_1) and (W) are determined by the first-order Monte Carlo calculation.

The end result of each NEMESIS calculation is the total excited-state population distribution for a pair of vibrational levels, where the lower level of each pair may itself be an excited level. A cycling procedure between CHEMKIN and NEMESIS is used to step up the vibrational energy ladder until the top of the ladder is reached. Finally, the NEMESIS populations are passed to the SPCRAD module for line-of-sight spectral radiance computation.

2.2.4 The Geometry Module

The GEOMETRY module in SHARC calculates a set of parameters which characterizes the line-of-sight (LOS) trajectory. There are three general categories of LOS's which are supported by SHARC:

- observer to a specified source location,
- observer to space, and
- limb viewing (space to space).

In addition to defining the LOS, the GEOMETRY module also calculates the column densities for ambient and vibrationally excited atmospheric species.

GEOMETRY is designed to give the user considerable flexibility in defining the LOS. It computes a uniform set of path quantities from one of many possible subsets of parameters specified by the user. For example, consider the parameters necessary to define the LOS for a path from an observer at Point A to a source at Point B. The LOS between these points can be specified by defining the altitude, longitude, and latitude for Point A, and either the altitude, longitude, and latitude for Point B, or the range between A and B and the zenith and azimuthal angles defined by the LOS direction. The full range of geometry inputs are discussed in Section 7.

2.2.5 The SPCRAD Module

SPCRAD computes the LOS spectral radiance using a finite-difference form of the radiative transfer equation. The LOS properties are specified in homogeneous segments where each segment corresponds to the LOS path through a particular atmospheric layer. A single-line equivalent width approximation based on the Voigt lineshape is used to determine the segment transmittances and radiances. This approach enables the spectral radiance to be calculated at a spectral resolution as high as 0.1 cm^{-1}, although the resolution in the current version of SHARC is set at 0.5 cm^{-1}. Since the radiation computation is explicitly based on the difference of the upper and lower state populations, it is equally valid in both the NLTE and LTE regimes. Line strengths and locations are taken from a modified line file generated from the AFGL HITRAN line atlas[5] and augmented with additional lines from various hot bands (currently the O_3 hot bands around 10 μm).[6] The major modification to the line parameter data base was to decompose the energy of the lower state into vibrational and rotational energies. This enables the line strengths to be scaled separately for the rotational temperature and the NITE vibrational population of the lower level.

There is a trade-off between speed and accuracy when the atmosphere is layered into many homogeneous layers. The LOS radiance calculation depends linearly on the number of layers. Currently the atmospheres used by SHARC are layered by 2 km from 60 to 150 km and by 10 km steps from 150 to 300 km. For a limb calculation at a tangent height of 60 km up to 119 atmospheric layers are traversed by the LOS. In order to reduce the computational burden for such cases a user-selectable relayering option is available. When selected, this option is automatically applied to optically thin transitions where it is the total column density of excited states and not the individual segment column densities that drives the radiance prediction. In this case, the atmosphere is relayered by combining a number of adjacent layers into a single larger layer where the total column density is preserved and other properties, such as rotational and translational temperature, are appropriately averaged over the combined layers. Up to an order of magnitude increase in speed, with very little loss in accuracy, can be attained with this approximation.

2.2.6 The OUTPUT Module

The OUTPUT module writes data and error statements to four separate data files. The files are the error file which is called "SHARC.ERR", the general output file, "SHARC.OUT", the spectral radiance file "SHARC.SPC", and the 'population' file, which is named by the user.

"SHARC.ERR" will contain error and warning statements generated by a SHARC calculation. An error message is generated by a fatal problem in SHARC, and execution will stop after the error message is placed in the error file. A warning is not fatal to SHARC, but it may alert the user that only a partial calculation has been performed or that numerical difficulties have been encountered and fixed in some module of the code. The user should get in the habit of looking at the error file after every SHARC execution to insure that the full desired calculation was actually performed.

"SHARC.OUT" contains a summary of the output from each module. There are three levels of output which can be obtained from each SHARC module. The level of output is selected through the interactive menu and can be defined independently for several of the SHARC subroutines or modules. The first level contains a minimum amount of information. For example, the minimum amount of information on the model atmosphere would be simply the model atmosphere name. The next level of output provides more detailed information such as the number densities of the atmospheric species as a function of altitude, or the vibrational temperatures from the chemical kinetics module. Finally, the highest level of output provides intermediate results from within modules. This level of information may be necessary for "debugging" a problem encountered in SHARC, but is usually too detailed for day-to-day execution.

"SHARC.SPC" is the spectral radiance file and contains the spectral radiance in $W/sr/cm^2/cm^{-1}$ as a function of frequency in cm^{-1}. The resolution and frequency range is defined through the "SHARC.INP" file and/or the input module. Currently SHARC does not have a filter function routine. The data must be degraded by the application of a filter function after the SHARC calculation has been performed.

The population file saves the excited state populations and other necessary information so multiple SHARC calculations can be performed without re-calculating the populations each time. The population for each layer in the model atmosphere will change only when either a new model atmosphere is used, day and night conditions change, or a new solar zenith angle is defined. By saving the populations, a user can build up a library of population files for the model atmospheres of interest. Since the calculation of the NLTE populations requires roughly half of the calculation time required for a full SHARC run, considerable computational time can be saved by using population files.

2.3 Plotting Package

The plotting software is a separate package which can be used to plot the spectral output of a SHARC computation. The plotting program is a general x-y plotting package. It is interactive and has two menus of options. The plotting package reads an input file which is a format-free list of x,y pairs without any header information. After the input file is read, plotting options can be changed through interactive menus. Default options are provided for convenience when plotting a SHARC output spectrum. The software can also be used for other plotting tasks. The plot and axis titles can contain superscripts, subscripts, as well as Greek and special characters. The program is written in Fortran 77. The program is designed to be as device independent as possible. It requires only standard Calcomp calls to initialize and terminated plotting, and a standard Calcomp call to move the pen.

3. SHARC INPUT FILES

3.1 INTERPRETER Files

The INTERPRETER reads the symbolic description of a chemical kinetics mechanism from an ASCII input file and writes the information describing the mechanism to a binary output file (the "linking" file) for subsequent use by the CHEMKIN module in SHARC. The input required by the INTERPRETER is the species name used in the mechanism and the mechanism itself. An example of the CO chemical kinetics mechanism input file currently used by SHARC is given in Table 1.

The information contained in the input file is given in an 80-column card format. All input to the INTERPRETER is format free. The INTERPRETER checks each input card for proper syntax and writes self-explanatory diagnostic messages to the output file if bad syntax is encountered. If any errors are encountered, the INTERPRETER does not create the linking file. Therefore, the input must be error free before SHARC can be executed.

The rules for creating the INTERPRETER input file have been described in detail in Reference (4). Subsections 3.1.1 and 3.1.2 have reproduced this input procedure as previously described. Some changes to the information expected in the SHARC INTERPRETER input file are incorporated in these sections.

TABLE 1. CURRENT SHARC INTERPRETER REACTION MECHANISM INPUT FILE.

```
CO SHARC CHEMICAL KINETICS MECHANISM
SPECIES
N2  O2  O  CH4  CO2  H2O  NO  N2O  O3  CO
N2(0) N2(1) O2(0) O2(1)
CO(0) CO(1) CO(2)
END
REACTIONS
M + CO(1)  -  M + CO(0)                    6.67E-08    0.0   208.3     0.0
     N2/1.0/  O2/1.0/
M + CO(0)  -  M + CO(1)                    6.67E-08    0.0   208.3  3083.7
     N2/1.0/  O2/1.0/
M + CO(2)  -  M + CO(1)                    1.33E-07    0.0   208.3     0.0
     N2/1.0/  O2/1.0/
M + CO(1)  -  M + CO(2)                    1.33E-07    0.0   208.3  3045.6
     N2/1.0/  O2/1.0/
M + CO(2)  -  M + CO(0)                    1.33E-07    0.0   208.3     0.0
     N2/1.0/  O2/1.0/
M + CO(0)  -  M + CO(2)                    1.33E-07    0.0   208.3  6129.3
     N2/1.0/  O2/1.0/
O + CO(1)  -  O + CO(0)                    9.90E-08    0.0   118.1     0.0
O + CO(0)  -  O + CO(1)                    9.90E-08    0.0   118.1  3083.7
O + CO(2)  -  O + CO(1)                    1.98E-07    0.0   118.1     0.0
O + CO(1)  -  O + CO(2)                    1.98E-07    0.0   118.1  3045.6
O + CO(2)  -  O + CO(0)                    1.98E-07    0.0   118.1     0.0
O + CO(0)  -  O + CO(2)                    1.98E-07    0.0   118.1  6129.3
CO(0) + N2(1)  -  CO(1) + N2(0)            6.98E-13    0.0    25.6     0.0
CO(1) + N2(0)  -  CO(0) + N2(1)            6.98E-13    0.0    25.6   268.5
CO(0) + O2(1)  -  CO(1) + O2(0)            3.50E-10    0.0   124.0   844.4
CO(1) + O2(0)  -  CO(0) + O2(1)            3.50E-10    0.0   124.0     0.0
CO(1)  -  CO(0) + HV                        30.96      0.0     0.0     0.0
CO(2)  -  CO(1) + HV                        60.45      0.0     0.0     0.0
CO(2)  -  CO(0) + HV                         1.03      0.0     0.0     0.0
CO(0) + HV  -  CO(1)                          0.0      0.0     0.0     0.0
CO(0) + HV  -  CO(2)                          0.0      0.0     0.0     0.0
CO(1) + HV  -  CO(2)                          0.0      0.0     0.0     0.0
END
```

3.1.1 Species Cards

Each chemical species must be identified on a Species Card (or cards). Any set of up to 10 characters can be used as a species name, which must begin with a letter. Species names of more than 10 characters may be used by simply changing a parameter value and some related format statements in the INTERPRETER. The primary purpose of the Species Cards is to identify the atmospheric species, the vibrational states included in the chemical kinetics mechanism for the selected radiating species, and finally the order in which arrays of species information are referenced in SHARC.

The first Species Card must contain the word SPECIES starting in Column 1. It is then followed by any number of cards which identify the species. Species symbols may appear anywhere on the card, and those on the same card must be separated by blank spaces. After all the species have been given, the following card must contain the word END starting in Column 1. The rules for Species Cards are summarized in Table 2.

TABLE 2. SUMMARY OF THE RULES FOR SPECIES CARDS.

1.	The first (last) species Card must contain the word SPECIES (END) starting in Column 1. All other columns on this card are ignored.
2.	Species names are composed of up to 10-character symbols. The names cannot begin with the characters +, -, =, a parenthesis, or a number.
3.	Each species must be declared only once.
4.	Each species which subsequently appears in a reaction must be declared.
5.	The species declarations may appear anywhere on the cards.
6.	Any number of species declarations may appear on a card. More than one card may be used.
7.	Species declarations which appear on the same card must be separated by at least one blank space.
8.	A species declaration which begins on one card may not continue to the next card.
9.	One species declaration may end in Column 80 of one card and the next declaration may begin in Column 1 of the next card.

3.1.2 Reaction Mechanism Description

The reaction mechanism may involve any number of chemical reactions and/or energy transfer processes involving the species named on the Species Cards. If more than 6 species appear in a given reaction, some dimension statements in the INTERPRETER must be changed. In the present version, the energy transfer/reactive processes must be written explicitly in the forward and/or reverse directions. They may be three-body reactions with an arbitrary third body including the effects of enhanced third-body efficiencies. Processes may involve radiative relaxation or excitation (e.g., earthshine and/or sunshine).

The first Reaction Card must contain the word REACTIONS starting in Column 1. The following cards contain the reaction description together with the generalized Arrhenius/Schwartz-Slawsky-Herzfeld (SSH) rate coefficients. The reaction description is made up of Reaction Cards and perhaps Auxiliary Information Cards. The last card of the reaction description must contain the word END starting in Column 1.

3.1.2.1 Reaction Cards

Each Reaction Card is divided into two fields. The first field contains the symbolic description of the reaction while the second contains the Arrhenius/SSH rate coefficients. Both fields are format free, and blank spaces are ignored (except within a number or a species symbol). The reaction description, given in the first field, must be composed of the species symbols, coefficients, delimiters, and special symbols as summarized below.

Species Symbols
: Each species in a reaction is described with the unique sequence of characters exactly as they appear in the Species Cards.

Coefficients
: Any species symbol may be preceded by an integer coefficient. The coefficient simply has the meaning that there are that many moles of the particular species present as either reactants or products; e.g., 2OH is equivalent to OH + OH (non-integer coefficients are not allowed).

Delimiters

+ A plus sign is the delimiter between the reactant species and between the product species.

= Although an equality sign is still considered a legal delimiter (an equality sign formerly was the delimiter between the reactants and products for a reversible reaction), it currently has the same meaning as a minus sign.

\- A minus sign is the delimiter between the reactants and products for an irreversible reaction.

Special Symbols

M The symbol M stands for an arbitrary third body. Normally it would appear as both a reactant and a product. However, it has the identical meaning even if it appears only as a reactant or a product. In other words, an M anywhere in the reaction description indicates that a third body is participating in the reaction. In any reaction containing an M, species are specified to have third-body efficiencies, in which case the next card(s) must be Auxiliary Information cards (described below).

HV The symbol HV indicates that photon radiation ($h\nu$) is present as either a reactant or a product. If an HV appears in a reaction description, the wavelength of the radiation may be specified on an Auxiliary Information Card (described later).

E The symbol E is used to represent an electron. Electrons are treated just like any other species except that they are not composed of elements.

[An open bracket means that any following characters through the beginning of the numbers for the Arrhenius coefficients are comments on the reaction. For example, the comment may be used to give a reference to the source of the reaction and rate data.

A special case for reaction descriptions occurs if two or more species names are identical except for the last character in one of the names being a +, -, or = (e.g., NO, NO+). The INTERPRETER always seeks to find the longest possible species name between delimiters (+, -, =). Therefore, the species NO may not be followed directly by a + as a delimiter since this would be confused with the species NO+. To prevent this confusion, the species NO must be separated from the delimiter + by at least one blank space (e.g., the reaction NO+O+M = NO2+M must be written as NO +O+M = NO2+M). However, NO+ +E+M = NO +M may just as well be written as NO++M+E = NO +M as long as NO++ is not a species. There is no ambiguity in the convention, and the worst that can happen if the blank is not included before the delimiter is that an error message will be written from the INTERPRETER. The blank will have to be inserted by the user, but there is no possibility of having a reaction misinterpreted by the code and proceeding with an incorrect reaction.

The second field of the reaction card is used to define the Arrhenius/SSH rate coefficients A_i, β_i, C_i, and E_i. The rate constants are assumed to have the following functional form

$$k_i = A_i T^{\beta_i} \exp(-C_i/T^{1/3} - E_i/T) \quad . \tag{5}$$

The four numbers must appear in order: the first number being A_i, the second being β_i, the third being C_i, and the fourth being E_i. At least one blank space must separate the first number and the last symbol in the reaction or the comment. The four numbers must be separated by at least one blank space; be stated in either integer, floating point, or E format (e.g., 123 or 123.0 or 12.3E1) and have units associated with them. The default units for A_i are cgs (cm, sec, K, and molecules), the exact units depending on the reaction. The factor β_i is dimensionless. The default units for the SSH parameters and activation energies are $K^{1/3}$ and K, respectively.

Table 3 is a summary of the Reaction Card rules, and examples of some reaction cards are shown in Table 1.

TABLE 3. SUMMARY OF THE RULES FOR REACTION CARDS.

1. The first (last) Reaction Card must contain the word REACTIONS (END) starting in Column 1. All other columns on this card are ignored. (The END card would follow the last Auxiliary Information Card, if one was used for the last reaction).

2. The reaction description can begin anywhere on the card. All blank spaces, except those within species symbols and within coefficients, are ignored.

3. If some species names end with either the characters +, -, or =, and there are other species names which are identical to those except that they don't end in a +, -, or =, then in the reaction description the latter species names must be separated from +, -, or = delimiters by at least one blank space.

4. Each reaction description must use only one card and may not continue onto the next card.

5. Four numbers for the Arrhenius/SSH coefficients must appear on each Reaction Card, must occupy the last non-blank entries on the card, must be separated from the reaction description by at least one blank space, must be in the order (A_i, β_i, C_i, and E_i), and must be separated by at least one blank space. No blanks are allowed within the numbers themselves.

6. Comments are any characters following an open bracket and up to within one blank space of the first Arrhenius coefficient. The comments are written on on the output file along with the reaction description, but otherwise ignored within the code.

3.1.2.2 Auxiliary Information Cards

If a reaction contains an M as third body and/or it contains an HV to denote radiation, the card or cards following that reaction card may be Auxiliary Information Cards. These cards specify third-body efficiencies of certain species or specify radiation wavelength. Any species which acts as a third body must be declared as one of the species on the Species Cards.

The format of the card is a name (either a species name or the characters HV) followed by a number (either integer, floating point, or E format delimited by slashes(/). For enhanced third-body efficiencies, the name is the species name of the enhanced third body, and the number is its enhanced efficiency factor. For wavelength specification, the symbols HV are followed by the wavelength.

Any number of third-body efficiencies may be included, and each Auxiliary Information Card may contain one or more efficiency factors. If more than 6 species have are specified as third bodies in any one reaction, some dimensioning needs to be changed in the INTERPRETER. Also, the radiation wavelength may appear on a separate card, or it may be on the same card as a third-body efficiencies specification. Thus more than one Auxiliary Information Card may be used for any one reaction. Examples of auxiliary information are shown in Table 1. The above rules are summarized in Table 4.

TABLE 4. SUMMARY OF THE RULES FOR AUXILIARY INFORMATION CARDS.

1.	Auxiliary Information Cards may only follow Reaction Cards which contain an M or an HV.
2.	A species may have only one third-body efficiency associated with it in any one reaction.
3.	Only one radiation wavelength may be declared in a reaction.
4.	The order in which the enhanced third-body declarations are given is the order in which arrays of third-body information are referenced in the subroutine package. The order in which the radiation wavelength appears with respect to enhanced third-body information is unimportant.
5.	Third-body (or wavelength) information may appear anywhere on the card.
6.	Any number of third-body efficiencies may appear on a card. Thus more than one card may be used.
7.	Third-body declarations or radiation wavelength specifications which appear on the same card must be separated by at least one blank space.
8.	A third-body (or wavelength) declaration which begins on one card may not continue on to the next card.
9.	One declaration (third-body efficiency or wavelength) may end in column 80 of one card, and the next declaration may begin in Column 1 of the next card.
10.	Any blank spaces between the species symbol (or HV) and the first slash are ignored, and any blanks between the slashes and the efficiency factor (or wavelength) are also ignored. However, no blank spaces are allowed within the factor (or wavelength).

3.2 Molecular States Files

The molecular states files are designed to supply the following information to SHARC:

- Identification of the molecular radiator;
- Definition of the vibrational energies and degeneracies associated with the vibrational states included in the chemical kinetics mechanism;

- Definition of the vibrational transitions (i.e., molecular bands) which will be treated by NEMESIS and SPCRAD. Note that a transition may be considered by NEMESIS but not by SPCRAD; and
- Definition of the effective earthshine temperature for each transition considered by NEMESIS.

The molecular states file is written in ASCII format. The information is input in an 80 column format and is format free. The SHARC CO molecular states file is given in Table 5. As the structure of the molecular states file is described, the reader should refer back to Table 5 as an example of the file organization.

The first line in the states file identifies the radiating species (which must be the first entry on this line) being considered by SHARC. Any information contained on this line after the radiating species identification is treated only as a comment and is subsequently ignored by the code. The next line must contain the identifier ENERGIES starting in Column 1, and thus signals the start of the list of vibrational-state energies and degeneracies. This line is followed by any number of lines which must each contain three numbers which identify the particular vibrational state (using the standard AFGL notation), the energy of that state (in cm^{-1}), and the degeneracy of that state, respectively. The three numbers must be separated by at least one blank, and may be integer, floating point, or exponential format. After all

TABLE 5. SHARC CO MOLECULAR STATES INPUT FILE.

```
CO VIBRATIONAL STATES AND TRANSITIONS
ENERGIES AND DEGENERACIES
 0      0.000     1
 1   2143.272     1
 2   4260.063     1
END
TRANSITIONS
 1-0      230.0     1
 2-0      280.0     1
 2-1      280.0     1
END
```

the vibrational states have been listed, the next line must contain the word END beginning in Column 1.

The next section of the molecular states file lists the vibrational transitions information. The first line following the END card must contain the word TRANSITIONS starting in Column 1. This line is followed by as many lines as necessary to identify: each vibrational transition considered by NEMESIS, the effective earthshine temperature (in K) for the transition, and whether or not to compute the radiance along the observer LOS for the transition. The vibrational transition is listed as "U-L" where "U" denotes the upper state and "L" denotes the lower state for the transition. The minus, "-", is the delimiter which separates the upper and lower states in the transition. It is important to note that a transition in the molecular states file must have the corresponding radiative relaxation and excitation processes listed in the chemical kinetics mechanism (compare Tables 1 and 5). The LOS radiance option is defined as follows:

- 0 - Radiance is <u>not</u> computed for this transition,
- 1 - Radiance is computed for this transition.

Although the radiance may not be computed for a particular transition, it may be important to include the transition in the states file for the NEMESIS calculation. The vibrational transition, effective earthshine temperature, and LOS radiance option must be separated by at least one blank. After all the vibrational transitions information have been given, a line containing the word END beginning in Column 1 must follow.

3.3 Molecular Bands Files

The molecular bands files are used to input line strength information necessary for the CHEMKIN and NEMESIS modules. CHEMKIN uses the information to obtain the altitude-dependent earthshine and sunshine excitation rates, while NEMESIS uses the information to calculate the enhancement of molecular excited-state populations due to radiative trapping and atmospheric emission.

Although both CHEMKIN and NEMESIS could directly use the modified HITRAN line compilation, this would be extremely time consuming due to the large number of lines. It is much more efficient to discretize the line strength distribution. Finite width bins are chosen in which a single average line is determined and a degeneracy equal to the actual number of lines from the exact distribution is assigned to the average line. In the limit of infinitesimal width bins the exact line strength distribution is recovered. For reasonable choices of bin widths (presently three bins per order of magnitude), the number of lines that need be considered can be reduced by several orders of magnitude without significant loss of computational accuracy. An additional quantity, the cumulative line strength probability sum, is used to choose a line strength value for each Monte Carlo simulated emission event in NEMESIS.

The molecular bands file indicates the vibrational transition along with the number of lines in a bin, the average strength in the bin, and the probability of finding a line in the bin. This information suffices to completely characterize the discretized line strength distribution. The file is written in ASCII format assuming an 80 column line and is format free. The SHARC CO molecular bands file is given in Table 6. Again, the reader should refer back to Table 6 as an example of the file organization.

The first line in the bands file identifies the molecular species (which must be the first entry on this line) for which the file has been created. The information contained on this line after the species identification is treated only as a comment and is ignored by the code. The molecular species is checked against the radiating species identified in the molecular states file to ensure a consistent set of files is being used. The next line contains the vibrational transition which is then followed by a list of the line strength parameters. As in the molecular states file, the vibrational transition is listed as "U-L" where "U" denotes the upper state, and "L" denotes the lower state for the transition. The minus, "-", is the delimiter which separates the upper and lower states in the transition. Each transition listed in the molecular states file must have a corresponding entry in the molecular bands file. The lines following vibrational transition describe the line strength distribution. Each line must contain four numbers which characterize the particular line strength distribution bin. The entries must be in the following order: (1) the bin number (not currently used by the code), (2) the number of lines in the bin, (3) the average line strength in

TABLE 6. SHARC CO MOLECULAR BANDS INPUT FILE.

CO	BAND	TRANSITIONS			
	1 -	0	G	S	PSUM
		1	2	.506E-18	.1030
		2	21	.350E-18	.8510
		3	7	.136E-18	.9479
		4	4	.710E-19	.9768
		5	5	.313E-19	.9927
		6	2	.142E-19	.9956
		7	4	.716E-20	.9985
		8	2	.322E-20	.9992
		9	3	.162E-20	.9997
		10	7	.441E-21	1.0000
END					
	2 -	0	G	S	PSUM
		1	18	.307E-20	.7344
		2	8	.157E-20	.9010
		3	6	.802E-21	.9649
		4	5	.349E-21	.9881
		5	3	.156E-21	.9943
		6	3	.773E-22	.9974
		7	4	.336E-22	.9992
		8	2	.145E-22	.9995
		9	3	.725E-23	.9998
		10	7	.178E-23	1.0000
END					
	2 -	1	G	S	PSUM
		1	1	.101E-17	.0526
		2	18	.766E-18	.7741
		3	10	.326E-18	.9445
		4	4	.144E-18	.9747
		5	3	[illegible]19	.9868
		6	5	[illegible]E-19	.9969
		7	4	.149E-19	1.0000
END					

the bin (cm^{-1}/molecule/cm^{-2}), and (4) the cumulative probability corresponding to the bin. The cumulative probability for bin I is

$$\sum_{i=1}^{I} P_i \qquad (6)$$

where P_i is the probability of finding a line of a given strength in bin i. Thus for the last bin the cumulative probability must be unity. The four numbers contained on the line must be separated by at least one blank, and may be integer, floating point, or exponential format. After all the line strength bins have been listed for the particular transition, the next line must contain the word END beginning in Column 1.

3.4 Modified HITRAN Line File

The augmented HITRAN[5] line file used by SHARC includes line parameters for CO, CO_2, H_2O, O_3, and NO. There are a total of 95,659 lines in the file, although the bands currently supported by SHARC will use 72,314 of the lines. The other lines are for transitions which will be supported in future versions of SHARC. The lines in the file have been modified to speed up the LOS spectral radiance calculation. The first modification was to separate the total energy of the lower state, E", into vibrational, E_V, and rotational, E_R, components. SHARC requires the separate E_V and E_R to properly scale the line strength since there are different vibrational and rotational temperatures. Computational time is saved by storing E_V and E_R rather than re-calculating them in the spectral radiance module.

The standard HITRAN line strengths have also been modified. The temperature-dependent scaling factors evaluated at the reference temperature, T_s = 296 K, have been removed from the strengths. This modification speeds up the spectral radiance calculation by eliminating the calculations which depend on T_s. Although the CPU savings realized by removing T_s is fairly small per line, a typical calculation uses thousands of lines and, therefore, the total savings can be significant. The line strength, SR, stored in the database is given by:

$$SR = S(T_s)\ Q_v(T_s)\ Q_r(T_s)\ \exp(C_2 \frac{E''}{T_s})\ [1 - \exp(-C_2 \frac{W_o}{T_s})]^{-1} \tag{7}$$

where $S(T_s)$ is the standard HITRAN line strength, W_o is the transition wavenumber, Q_v and Q_r are the vibrational and rotational partition functions, respectively.

The following database parameters are used in the spectral radiance module of SHARC:

MOL	- AFGL molecular species identification label
ISO	- AFGL molecular species isotope identification label
W_o	- transition frequency (cm^{-1})
SR	- modified line strength (cm^{-1}/molecule/cm^{-2})

GAM	-	Lorentz halfwidth (cm^{-1})
E"	-	total energy of lower state (cm^{-1})
E_V	-	vibrational energy of lower state (cm^{-1})
E_R	-	rotational energy of lower state (cm^{-1})
IUP	-	upper state vibrational label
ILOW	-	lower state vibrational label.

In addition to the above parameters, there are a few parameters which are in the database and are not currently used by SHARC, but are included to support future extensions. These include a self-broadening halfwidth, a coefficient of temperature dependence of air-broadened halfwidth, and upper and lower state local quanta indices. An example of the database is given in Table 7, we have included only the parameters currently used by SHARC. This part of the line file includes lines for H_2O (MOL=1), CO_2 (MOL=2), and NO (MOL=8).

The line file used by SHARC is written in binary format. Using a binary representation of the file saves storage space and makes the reading time shorter than if the file was stored in an ASCII format. The file is provided on the SHARC computer tape in an ASCII format along with a program which converts the file to binary.

TABLE 7. PART OF SHARC LINE PARAMETER DATABASE.

MOL	ISO	W_o	SR	GAM	E"	E_V	E_R	IUP	ILOW
1	1	1950.4490	.432E-16	.0907	2000.8660	1594.7500	406.1160	4	2
2	1	1950.6992	.727E-21	.0727	197.4163	.0000	197.4163	6	1
2	1	1950.8227	.212E-19	.0646	1308.6709	667.3800	641.2909	11	2
8	1	1950.8421	.149E-18	.0500	4514.8540	3724.1699	790.6841	4	13
8	1	1950.8650	.103E-15	.0490	1189.3781	.0000	1189.3781	2	1
8	1	1950.8710	.103E-15	.0490	1189.4390	.0000	1189.4390	2	1
8	1	1950.9238	.248E-19	.0610	3737.2720	3724.1699	13.1021	4	13
2	1	1950.9821	.191E-19	.0649	1276.4469	667.3800	609.0669	11	2
1	1	1951.1300	.113E-17	.0620	447.2520	.0000	447.2520	2	1
2	1	1951.1772	.199E-20	.0892	1390.5258	1388.1851	2.3407	19	5
2	1	1951.1910	.358E-20	.0876	1395.9884	1388.1851	7.8033	19	5
2	1	1951.2126	.518E-20	.0860	1404.5724	1388.1851	16.3873	19	5
2	1	1951.2421	.677E-20	.0843	1416.2777	1388.1851	28.0927	19	5
2	1	1951.2794	.835E-20	.0826	1431.1040	1388.1851	42.9189	19	5
2	1	1951.3244	.996E-20	.0810	1449.0513	1388.1851	60.8662	19	5
3	1	1951.3430	.679E-18	.0638	652.3090	.0000	652.3090	14	1
2	1	1951.3772	.115E-19	.0793	1470.1191	1388.1851	81.9341	19	5
1	1	1951.4230	.137E-16	.0820	1907.4520	1594.7500	312.7020	4	2
2	1	1951.4375	.131E-19	.0777	1494.3074	1388.1851	106.1223	19	5
2	1	1951.5055	.147E-19	.0761	1521.6157	1388.1851	133.4307	19	5
2	1	1951.5810	.163E-19	.0747	1552.0435	1388.1851	163.8584	19	5
2	1	1951.6639	.179E-19	.0733	1585.5906	1388.1851	197.4055	19	5
2	1	1951.7541	.195E-19	.0721	1622.2563	1388.1851	234.0713	19	5
8	1	1951.7804	.151E-18	.0500	4588.4712	3724.1699	864.3013	4	13
8	1	1951.8076	.551E-19	.0570	5738.5718	5544.1250	194.4468	5	14
2	1	1951.8515	.211E-19	.0710	1662.0403	1388.1851	273.8552	19	5
2	1	1951.9560	.227E-19	.0699	1704.9419	1388.1851	316.7568	19	5

3.5 Model Atmosphere Files

The atmospheric models supplied with SHARC are based on the AFGL HAIRM(6) atmospheric models. There are currently daytime and nighttime models for:

- 1976 standard atmosphere,
- 15^o latitude annual,
- 30^o latitude summer, winter,
- 45^o latitude spring/fall, summer, winter, and
- 60^o latitude summer, winter,

for exo-atmospheric temperatures of 600, 1000 and 1500 K. These models include temperature and number densities for N_2, O_2, O, CH_4, CO_2, H_2O, NO, N_2O, O_3, and CO as a function of altitude. The profiles are layered into 60 homogeneous layers (61 layer boundaries) defined in 2 km increments from 60 to 150 km and in 10 km increments from 150 to 300 km.

The model atmosphere file is contained in an 80 column, format free ASCII file. The input file is checked for proper syntax and self-explanatory diagnostic messages are written to the SHARC error file if unacceptable syntax is encountered.

The user can define a new atmosphere file by following a set of simple rules. A SHARC atmospheric file is structured as a series of input parameter identification cards followed by the actual input values (at least one) and an END card that denotes the end of the parameter input.

As an example, the daytime 1976 Standard Atmosphere Model input file provided with SHARC is shown in Table 8. As the various input parameters are described, it should help the user to refer back to Table 8.

TABLE 8. CURRENT SHARC 1976 STANDARD MODEL ATMOSPHERE INPUT FILE.

```
ATMOSPHERE NAME
SAT1976.DAT
END
NUMBER OF BOUNDARIES
 61
END
DAY-NIGHT VARIABLE AND EXOATMOSPHERIC TEMPERATURE
 DAY 1000.
END
SPECIES
O2 O CH4 CO2 H2O NO N2O CO N2 O3
END
ALTITUDES OF BOUNDARIES
 60  62  64  66  68  70  72  74  76  78  80  82  84  86  88  90
 92  94  96  98 100 102 104 106 108 110 112 114 116 118 120 122
124 126 128 130 132 134 136 138 140 142 144 146 148 150 160 170
180 190 200 210 220 230 240 250 260 270 280 290 300
END
TEMPERATURES
  2.4706E+02 2.4157E+02 2.3607E+02 2.3058E+02 2.2509E+02 2.1959E+02
  2.1426E+02 2.1035E+02 2.0643E+02 2.0252E+02 1.9861E+02 1.9470E+02
  1.9078E+02 1.8687E+02 1.8687E+02 1.8687E+02 1.8698E+02 1.8774E+02
  1.8931E+02 1.9172E+02 1.9508E+02 1.9953E+02 2.0531E+02 2.1289E+02
  2.2329E+02 2.4000E+02 2.6400E+02 2.8800E+02 3.1200E+02 3.3600E+02
  3.6000E+02 3.8355E+02 4.0622E+02 4.2804E+02 4.4904E+02 4.6927E+02
  4.8838E+02 5.0748E+02 5.2519E+02 5.4290E+02 5.5932E+02 5.7573E+02
  5.9095E+02 6.0617E+02 6.2028E+02 6.3439E+02 6.9629E+02 7.4757E+02
  7.9007E+02 8.2531E+02 8.5456E+02 8.7679E+02 8.9901E+02 9.0739E+02
  9.1578E+02 9.3338E+02 9.5099E+02 9.5724E+02 9.6350E+02 9.6976E+02
  9.7601E+02
END
N2 DENSITIES
```

```
   5.0401E+15 3.9179E+15 3.0285E+15 2.3272E+15 1.7774E+15 1.3487E+15
   1.0158E+15 7.5547E+14 5.5885E+14 4.1110E+14 3.0067E+14 2.1859E+14
   1.5792E+14 1.1335E+14 7.9416E+13 5.5653E+13 3.8990E+13 2.7250E+13
   1.9010E+13 1.3255E+13 9.2490E+12 6.4652E+12 4.5314E+12 3.1853E+12
   2.2430E+12 1.5690E+12 1.1070E+12 8.0527E+11 6.0096E+11 4.5838E+11
   3.5627E+11 2.8177E+11 2.2647E+11 1.8454E+11 1.5219E+11 1.2683E+11
   1.0674E+11 9.0442E+10 7.7300E+10 6.6417E+10 5.7475E+10 4.9948E+10
   4.3665E+10 3.8305E+10 3.3772E+10 2.9862E+10 1.6954E+10 1.0227E+10
   6.4440E+09 4.1942E+09 2.7983E+09 1.9071E+09 1.3137E+09 9.2566E+08
   6.5502E+08 4.6161E+08 3.2777E+08 2.3676E+08 1.7154E+08 1.2467E+08
   9.0872E+07
END
O2 DENSITIES
   1.3521E+15 1.0510E+15 8.1245E+14 6.2433E+14 4.7682E+14 3.6181E+14
   2.7251E+14 2.0267E+14 1.4992E+14 1.1029E+14 8.0661E+13 5.8641E+13
   4.2366E+13 3.0409E+13 2.1305E+13 1.4930E+13 1.0460E+13 7.3104E+12
   5.0997E+12 3.5560E+12 2.4812E+12 1.7344E+12 1.2156E+12 8.5452E+11
   6.0174E+11 4.2093E+11 2.8647E+11 2.0163E+11 1.4599E+11 1.0828E+11
   8.1997E+10 6.3292E+10 4.9716E+10 3.9644E+10 3.2027E+10 2.6169E+10
   2.1614E+10 1.7985E+10 1.5105E+10 1.2762E+10 1.0864E+10 9.2931E+09
   7.9998E+09 6.9133E+09 6.0066E+09 5.2357E+09 2.7792E+09 1.5760E+09
   9.3719E+08 5.7740E+08 3.6549E+08 2.3673E+08 1.5519E+08 1.0418E+08
   7.0274E+07 4.7246E+07 3.2037E+07 2.2115E+07 1.5320E+07 1.0649E+07
   7.4278E+06
END
O DENSITIES
   1.2000E+10 1.3291E+10 1.4720E+10 1.6304E+10 1.8058E+10 2.0000E+10
   2.4915E+10 3.1037E+10 3.8664E+10 4.8164E+10 6.0000E+10 6.7650E+10
   7.6275E+10 8.6000E+10 1.5100E+11 2.4400E+11 3.4300E+11 4.1600E+11
   4.4700E+11 4.4300E+11 4.3000E+11 4.0100E+11 3.6200E+11 3.1900E+11
   2.7500E+11 2.3000E+11 1.8900E+11 1.5600E+11 1.3000E+11 1.1000E+11
   9.2800E+10 7.9883E+10 6.8765E+10 5.9812E+10 5.2567E+10 4.6200E+10
   4.1344E+10 3.6998E+10 3.3303E+10 3.0153E+10 2.7300E+10 2.4951E+10
   2.2803E+10 2.0934E+10 1.9303E+10 1.7800E+10 1.2400E+10 9.0000E+09
   6.7500E+09 5.1800E+09 4.0500E+09 3.2353E+09 2.5845E+09 2.0869E+09
   1.7032E+09 1.3900E+09 1.1471E+09 9.4668E+08 7.8444E+08 6.5265E+08
   5.4300E+08
END
CH4 DENSITIES
   6.0287E+13 4.6863E+13 3.6225E+13 2.7837E+13 2.1260E+13 1.6132E+13
   1.2151E+13 9.0365E+12 6.6846E+12 4.9174E+12 3.5965E+12 2.6146E+12
   1.8890E+12 1.3558E+12 9.4994E+11 6.6570E+11 4.6638E+11 3.2595E+11
   2.2738E+11 1.5855E+11 1.1063E+11 7.7334E+10 5.4202E+10 3.8101E+10
   2.6830E+10 1.8768E+10 1.1886E+10 7.8350E+09 5.3408E+09 3.7462E+09
   2.6932E+09 1.9803E+09 1.4860E+09 1.1348E+09 8.7986E+08 6.9127E+08
   5.4987E+08 4.4130E+08 3.5797E+08 2.9242E+08 2.4096E+08 1.9970E+08
   1.6670E+08 1.398[illegible]E+08 1.1798E+08 9.9943E+07 4.6388E+07 2.3255E+07
   1.2322E+07 6.8043E+06 3.8779E+06 2.2693E+06 1.3479E+06 8.2143E+05
   5.0361E+05 3.0824E+05 1.9067E+05 1.2024E+05 7.6155E+04 4.8442E+04
   3.0945E+04
END
CO2 DENSITIES
   2.0268E+12 1.5755E+12 1.2178E+12 9.3586E+11 7.1474E+11 5.4235E+11
   4.0849E+11 3.0380E+11 2.2473E+11 1.6532E+11 1.2091E+11 8.7901E+10
   6.3505E+10 4.5582E+10 3.1936E+10 2.2380E+10 1.5679E+10 1.0958E+10
```

```
   7.6444E+09 5.3303E+09 3.7193E+09 2.5999E+09 1.8222E+09 1.2809E+09
   9.0199E+08 6.3096E+08 3.8519E+08 2.4553E+08 1.6228E+08 1.1063E+08
   7.7452E+07 5.5552E+07 4.0724E+07 3.0420E+07 2.3095E+07 1.7785E+07
   1.3878E+07 1.0934E+07 8.7128E+06 6.9961E+06 5.6699E+06 4.6236E+06
   3.7995E+06 3.1382E+06 2.6089E+06 2.1781E+06 9.4394E+05 4.4431E+05
   2.2195E+05 1.1589E+05 6.2601E+04 3.4781E+04 1.9643E+04 1.1394E+04
   6.6526E+03 3.8811E+03 2.2906E+03 1.3793E+03 8.3449E+02 5.0729E+02
   3.0983E+02
END
H2O DENSITIES
   3.1197E+10 2.3833E+10 1.8099E+10 1.3412E+10 1.0053E+10 7.3407E+09
   5.3121E+09 3.7088E+09 2.5646E+09 1.7549E+09 1.1552E+09 7.2318E+08
   4.3819E+08 2.6614E+08 1.5256E+08 8.9093E+07 4.7853E+07 2.6174E+07
   1.3187E+07 5.6585E+06 2.4677E+06 1.3800E+06 8.7048E+05 5.6092E+05
   3.7104E+05 2.5118E+05 1.9400E+05 1.5326E+05 1.2339E+05 1.0096E+05
   8.3768E+04 7.0425E+04 5.9953E+04 5.1585E+04 4.4798E+04 3.9220E+04
   3.4608E+04 3.0688E+04 2.7403E+04 2.4562E+04 2.2144E+04 2.0025E+04
   1.8196E+04 1.6575E+04 1.5161E+04 1.3895E+04 9.3398E+03 6.5788E+03
   4.7925E+03 3.5798E+03 2.7255E+03 2.1104E+03 1.6458E+03 1.3097E+03
   1.0451E+03 8.2883E+02 6.6058E+02 5.3465E+02 4.3358E+02 3.5230E+02
   2.8683E+02
END
NO DENSITIES
   9.0000E+07 7.2000E+07 5.8000E+07 4.6000E+07 3.7000E+07 2.9000E+07
   2.3000E+07 1.8000E+07 1.4000E+07 1.1500E+07 9.6000E+06 8.7000E+06
   8.2000E+06 8.7000E+06 1.0500E+07 1.4000E+07 1.8000E+07 2.3000E+07
   3.0000E+07 3.6000E+07 4.0000E+07 4.2000E+07 4.4000E+07 4.5000E+07
   4.4000E+07 4.3000E+07 4.2000E+07 4.0000E+07 3.9000E+07 3.7000E+07
   3.6000E+07 3.4769E+07 3.3579E+07 3.2377E+07 3.1166E+07 3.0000E+07
   2.8691E+07 2.7438E+07 2.6241E+07 2.5095E+07 2.4000E+07 2.2783E+07
   2.1627E+07 2.0530E+07 1.9489E+07 1.8500E+07 1.3500E+07 8.8105E+06
   5.7500E+06 3.6759E+06 2.3500E+06 1.6011E+06 1.0909E+06 7.4322E+05
   5.0637E+05 3.4500E+05 2.4436E+05 1.7308E+05 1.2259E+05 8.6829E+04
   6.1500E+04
END
N2O DENSITIES
   6.4[illegible]47E+10 5.0175E+10 3.8785E+10 2.9804E+10 2.2762E+10 1.7272E+10
   1.3009E+10 9.6751E+09 7.1570E+09 5.2648E+09 3.8506E+09 2.7994E+09
   2.0225E+09 1.4517E+09 1.0171E+09 7.1274E+08 4.9934E+08 3.4899E+08
   2.4345E+08 1.6976E+08 1.1845E+08 8.2798E+07 5.8032E+07 4.0793E+07
   2.8726E+07 2.0094E+07 1.3924E+07 9.9633E+06 7.3239E+06 5.5086E+06
   4.2261E+06 3.3020E+06 2.6236E+06 2.1149E+06 1.7263E+06 1.4245E+06
   1.1876E+06 9.9721E+05 8.4490E+05 7.1985E+05 6.1786E+05 5.3271E+05
   4.6212E+05 4.0237E+05 3.5216E+05 3.0917E+05 1.6973E+05 9.9267E+04
   6.0764E+04 3.8478E+04 2.5006E+04 1.6614E+04 1.1164E+04 7.6784E+03
   5.3049E+03 3.6515E+03 2.5337E+03 1.7892E+03 1.2676E+03 9.0093E+02
   6.4239E+02
END
O3 DENSITIES
   7.3300E+09 4.4000E+09 2.4000E+09 1.1000E+09 5.2000E+08 2.0000E+08
   9.0000E+07 4.6000E+07 2.7000E+07 1.9000E+07 1.8000E+07 2.2000E+07
   3.8000E+07 4.5000E+07 4.5000E+07 3.8000E+07 2.8000E+07 2.0000E+07
   1.4000E+07 9.0000E+06 5.0000E+06 3.4951E+06 2.4497E+06 1.7220E+06
   1.2126E+06 8.4823E+05 4.9947E+05 3.0806E+05 1.9755E+05 1.3095E+05
   8.9319E+04 6.2521E+04 4.4794E+04 3.2742E+04 2.4351E+04 1.8386E+04
```

```
  1.4079E+04 1.0893E+04 8.5299E+03 6.7346E+03 5.3694E+03 4.3097E+03
  3.4873E+03 2.8374E+03 2.3245E+03 1.9131E+03 7.7511E+02 3.4296E+02
  1.6168E+02 7.9913E+01 4.0952E+01 2.1623E+01 1.1622E+01 6.4220E+00
  3.5742E+00 1.9892E+00 1.1211E+00 6.4513E-01 3.7317E-01 2.1697E-01
  1.2680E-01
END
CO DENSITIES
  9.0366E+08 1.0035E+09 1.0860E+09 1.1922E+09 1.2291E+09 1.2090E+09
  1.2489E+09 1.2578E+09 1.2167E+09 1.1583E+09 1.1552E+09 1.1757E+09
  1.1124E+09 1.1323E+09 1.0680E+09 1.0691E+09 1.0486E+09 9.7717E+08
  8.7642E+08 7.8090E+08 7.1070E+08 5.7959E+08 4.6426E+08 3.6714E+08
  2.7577E+08 2.0094E+08 1.4178E+08 1.0313E+08 7.6969E+07 5.8709E+07
  4.5631E+07 3.6091E+07 2.9007E+07 2.3638E+07 1.9494E+07 1.6245E+07
  1.3673E+07 1.1585E+07 9.9018E+06 8.5079E+06 7.3624E+06 6.3984E+06
  5.5935E+06 4.9070E+06 4.3264E+06 3.8255E+06 2.1721E+06 1.3103E+06
  8.2563E+05 5.3739E+05 3.5856E+05 2.4437E+05 1.6834E+05 1.1862E+05
  8.3942E+04 5.9158E+04 4.2006E+04 3.0343E+04 2.1986E+04 1.5979E+04
  1.1648E+04
END
```

The following input parameter identification cards must be contained in the user-defined atmospheric model file in the order listed:

- ATMOSPHERE NAME Card
- NUMBER OF LAYER BOUNDARIES Card
- DAY-NIGHT VARIABLE AND EXOATMOSPHERIC TEMPERATURE Card
- SPECIES Card
- ALTITUDES Card
- TEMPERATURES Card
- SPECIES DENSITIES Card.

Each input parameter identification card must start in Column 1. After the appropriate data corresponding to the identification card has been entered into the file, the next line must contain the word END beginning in Column 1. The information required after each parameter identification card is detailed below.

The line following the ATMOSPHERE NAME card must contain the alphanumeric name of the atmospheric file being used. After the END card (and following the NUMBER OF LAYER BOUNDARIES card), the number of layer boundary points should be entered. There must be at least two layer boundaries, and the current maximum is 61 boundaries. Next the DAY-NIGHT parameter and the EXOATMOSPHERIC TEMPERATURE should be defined exactly in the order stated and separated by at least a blank space. The DAY-NIGHT parameter is entered as either DAY or NIGHT. For a user-defined atmosphere the DAY-NIGHT parameter must be present, but it is not actually used by SHARC. Also, for a user-defined atmosphere the exoatmospheric temperature should be input as 0.0. After the SPECIES card, a list of atmospheric species for which number densities are given is input. This list of species must include all molecular species desired in the model atmosphere. The same rules apply to entering the atmospheric species as those given for the INTERPRETER (see Subsection 3.1.1). Also, each species listed in the atmosphere file must be listed as a species in the interpreter file. The next input considered is the altitudes of the layer boundaries. Any number of lines may be entered to define the layer altitudes. The layers must be entered in ascending order. The input units are km and are converted to cm internally. Next the kinetic temperatures and species number densities are entered in such a way as to correspond to the layer boundary altitudes. The number of entries for the temperatures and each species number densities must equal the value of the parameter entered for the number of layer boundaries. The temperatures are input in degrees Kelvin and the number densities are input in molecules/cm^3. After the line containing the END card for the TEMPERATURE data, a card with one of the valid atmospheric species names (followed by a blank and the word DENSITIES) indicates the beginning of the atmospheric number densities input for this species, see Table 8 for clarification. Again, this data is followed by the word END beginning in Column 1. e procedure for the atmospheric species is continued until number densities have been defined for all atmospheric species listed in the SPECIES section of the file.

4. RUNNING SHARC

4.1 Overview

This section is intended as a ready reference for the user who has some familiarity with running SHARC, but may want a quick tutorial for the execution procedure. In addition to providing somewhat brief instructions taking the user from the input files through to a plot of spectral radiance, file names used by the INTERPRETER, SHARC, and the PLOTTING PACKAGE are also presented. Of course, for detailed instructions concerning the creation of input files or definition of input variables, the user should refer to the appropriate sections of this report.

Prior to running SHARC, the "linking" files must be created for each molecular radiator. This is accomplished by running the INTERPRETER once for each radiator. The INTERPRETER expects an ASCII input file named INTERP.INP, which contains the chemical kinetics mechanism for producing vibrationally excited states for the selected radiator. The structure for this input file is discussed in some detail in Section 3.1. After executing the INTERPRETER, two output files are created: INTERP.OUT and INTERP.LNK. The file INTERP.OUT is an ASCII file and contains information from the input file. The user should check this file to ensure that the INTERPRETER was successfully executed. Any error messages created during program execution will be written to this file. The file INTERP.LNK is a binary file (i.e., the "linking" file) which contains the chemical kinetics information required by SHARC. This file is only created if no errors were encountered during the INTERPRETER execution.

There are five chemical kinetics mechanism input files which are currently supplied with SHARC for CO, NO, CO_2, H_2O, and O_3. The input file names are summarized in Table 9. In order to create a "linking" file for one of the radiators, say CO, one would proceed as follows: (1) copy the file COKIN.DAT to INTERP.INP, (2) execute the INTERPRETER, (3) rename INTERP.OUT to COOUT.DAT, and (4) rename INTERP.LNK to COLINK.DAT. The file COLINK.DAT would then be used as the "linking" file for SHARC. This procedure should be carried out for each molecular radiator.

TABLE 9. SUMMARY OF THE FILES USED BY THE INTERPRETER.

INPUT	OUTPUT	LINKING
H2OKIN.DAT	H2OOUT.DAT	H2OLINK.DAT
CO2KIN.DAT	CO2OUT.DAT	CO2LINK.DAT
O3KIN.DAT	O3OUT.DAT	O3LINK.DAT
COKIN.DAT	COOUT.DAT	COLINK.DAT
NOKIN.DAT	NOOUT.DAT	NOLINK.DAT

To execute SHARC the user must first prepare 18 separate input files. Many of these files require no modification by the user unless the user desires to change and/or supplement the AFGL database provided with SHARC. The SHARC input and output files are summarized in Table 10. These files include:

- 5 Linking files (one for each molecular emitter),
- 5 States files (one for each molecular emitter),
- 5 Bands files (one for each molecular emitter),
- 1 Model atmosphere profile file (9 are provided),
- SHARC HITRAN file (binary version), and
- SHARC input file (SHARC.INP).

These files have been described in detail in Sections 3 and 4 of this manual. The Linking files are generated by running the INTERPRETER as described above. The states, bands, and model atmosphere files are provided on the SHARC computer tape, and require no modification. The binary SHARC HITRAN file is generated from an ASCII file provided on the SHARC computer tape. Forming this binary file and compiling/linking SHARC are described in detail in Appendix A. Finally the SHARC input file, SHARC.INP, must be available to SHARC, or a new SHARC.INP will be created. The input module and the SHARC.INP files are described in detail in Sections 4.2 - 4.4.

Once the user has all of the above files prepared, SHARC can be executed. SHARC can run in either an interactive or batch/background mode of operation. The interactive mode is useful in setting up new calculation scenarios, since the interactive input module can walk the user through the necessary input variables. For more experienced users, SHARC can be executed by circumventing the input module and making all changes to the SHARC.INP file with an editor.

The input module of SHARC is based on a menu-query system derived from the AFGL Auroral Atmospheric Radiance Code.[2] In general, typing a 0 will take the user up a level in the menu system, while typing a number greater than 0 will allow the user to input new information or enter a submenu. When a submenu is entered the current values for input variables are displayed to the user. This allows the user to scan the current input parameter values and decide if anything needs to be changed. There is a sample interactive session in Section 4.2.

After a successful SHARC calculation there will be four new ASCII output files. These files are:

- Error file (described in Section 5.1),
- General output file (described in Section 5.2),
- Population file (described in Section 5.3), and
- Plot file (described in Section 5.4).

The Error file, called SHARC.ERR should be empty if the calculation was performed without errors or warnings. The user should always check this file to insure the calculation was performed correctly The general output file, called SHARC.OUT, includes a summary of the calculation. The plotting file contains the spectral radiance ($W/sr/cm^2/cm^{-1}$) as a function of frequency (cm^{-1}) and is used as an input file for the SHARC plotting package or a user provided plotting package. The SHARC plotting package is an interactive menu-query plotting package and is described in detail in Section 6. The population file contains all of the necessary excited-state population information to allow the user to skip the CHEMKIN/NEMESIS modules of SHARC and go directly to the geometry and spectral radiance modules. Populations only depend on the model atmosphere, day/night conditions and solar zenith angle. Therefore, the same populations can be used for many different LOS's and bandpass configurations. This can save a large amount of computer time and gives the user the opportunity to set up a library of populations for future or often-used scenarios.

TABLE 10. SUMMARY OF THE FILES USED BY SHARC.

LINKING	STATES	BANDS	INPUT	OUTPUT
COLINK.DAT	COSTAT.DAT	COBAND.DAT	SHARC.INP	SHARC.ERR
NOLINK.DAT	NOSTAT.DAT	NOBAND.DAT	SHARC.LIN	SHARC.OUT
CO2LINK.DAT	CO2STAT.DAT	CO2BAND.DAT	SAT1976.DAT%	SHARC.SPC
H2OLINK.DAT	H2OSTAT.DAT	H2OBAND.DAT		POPNEW.DAT*
O3LINK.DAT	O3STAT.DAT	O3BAND.DAT		

% This is one of the 9 model atmosphere files supplied.

* User-supplied name.

4.2 Sample Interactive Session

This section will feature an illustrative interactive session with the SHARC input module. The prompts from SHARC are capitalized. User responses are contained in braces, { }. Text which is inserted in to the session to clarify user responses will be contained in < >.

In the interactive execution mode SHARC looks for the "SHARC.INP" input file. This file contains the user-supplied input parameters for SHARC (several of these files are supplied on the SHARC computer tape and discussed in the test case section of this manual). If "SHARC.INP" is not found, the input module will use a set of default values for all input parameters. Once SHARC has a set of input parameters, the input module displays the top-level input menu and the user can begin to set-up a new SHARC calculation. In this example, the initial default version of 'SHARC.INP' is listed in Table 11. After the user exits the interactive input module an new version of "SHARC.INP" is saved, this file is reproduced in Table 12.

Begin session:

{run SHARC}

<The main routine successfully opens the input file >
<called SHARC.INP and the main menu is displayed. >

STRATEGIC HIGH-ALTITUDE RADIANCE CODE
REVIEW OR MODIFY INPUT PARAMETERS

1. TITLE FOR CALCULATION*

```
       2. MODEL ATMOSPHERE
       3. NEMESIS CONTROL PARAMETERS
       4. MOLECULAR EMITTERS*
       5. SOLAR ZENITH ANGLE
       6. POPULATION FILE*
       7. LOS GEOMETRY*
       8. SPECTRAL INTERVAL AND RESOLUTION*
       9. OUTPUT DATA*
      * OPTIONS CAN BE CHANGED WHILE USING OLD POPULATION FILES

      10. UPDATE DEFAULT FILE AND EXIT FOR BATCH EXECUTION
      11. EXIT WITH NO UPDATE OF DEFAULT FILE

       ENTER # OF ITEM TO BE CHANGED
       0 TO CONTINUE SHARC EXECUTION
  {1}

             <The user can enter a number from 1 to 9 to enter a          >
             <submenu on topics 1 through 9.  Or by entering a value      >
             <of 10 the user can exit the input menu and update the       >
             <"SHARC.INP" file for a batch calculation.  Entering         >
             <an 11 will exit the sharc calculation without changing      >
             <the "SHARC.INP" file (used to quit SHARC when many input    >
             <parameters have been incorrectly entered) and entering a    >
             <0 will allow SHARC to continue interactive execution.       >
             <In this session we will start by entering a new title for   >
             <the calculation.                                            >

             <When entering a submenu the current values of parameters    >
             <are displayed.  Then the user is given the                  >
             <opportunity to keep the current values and return to the    >
             <main menu, or change the parameter values.                  >

       1.0 REVIEW OR MODIFY TITLE:

           TITLE =    OLD TEST CASE

       INPUT : 0 TO KEEP CURRENT TITLE
               1 TO INPUT NEW TITLE
  {1}

       INPUT TITLE: (MAXIMUM OF 68 CHARACTERS)
  {NEW TEST CASE}

             <After the new information has been entered, the submenu     >
             <will re-display the current information.                    >

       1.0 REVIEW OR MODIFY TITLE:

           TITLE =    NEW TEST CASE

       INPUT : 0 TO KEEP CURRENT TITLE
               1 TO INPUT NEW TITLE
  {0}
             <Entering a 0 here will return the user to the top menu.     >
```

```
     REVIEW OR MODIFY INPUT PARAMETERS

     1. TITLE FOR CALCULATION*
     2. MODEL ATMOSPHERE
     3. NEMESIS CONTROL PARAMETERS
     4. MOLECULAR EMITTERS*
     5. SOLAR ZENITH ANGLE
     6. POPULATION FILE*
     7. LOS GEOMETRY*
     8. SPECTRAL INTERVAL AND RESOLUTION*
     9. OUTPUT DATA*
    * OPTIONS CAN BE CHANGED WHILE USING OLD POPULATION FILES

    10. UPDATE DEFAULT FILE AND EXIT FOR BATCH EXECUTION
    11. EXIT WITH NO UPDATE OF DEFAULT FILE

     ENTER # OF ITEM TO BE CHANGED
     0 TO CONTINUE SHARC EXECUTION
{4}

           <The submenus can be accessed in any order. For example,    >
           <the next item we will change in this session is the        >
           <molecular emitters.  Therefore the user enters a 4.        >

     4.0 REVIEW OR MODIFY ATMOSPHERIC RADIATORS...

      CURRENTLY THERE ARE  1 RADIATORS
      EACH MOLECULAR RADIATOR REQUIRES THREE INPUT DATA SETS

     AFGL#  MOLECULE   LINKING FILE   STATES FILE  BAND FILE
       1      H2O       H2OLINK.DAT   H2OSTAT.DAT  H2OBAND.DAT


       TO ADD SPECIES INPUT THE AFGL #
       TO REMOVE SPECIES INPUT THE NEGATIVE AFGL #
       PLEASE INPUT ONE CHANGE AT A TIME.
       TYPE 0 TO RETURN TO MAIN MENU
{5}
           <To add CO as radiator enter a 5.  The AFGL numbers for     >
           <the supported molecular radiators will be displayed if     >
           <an incorrect, or unsupported molecule is selected.         >
           <As discussed in Section 4.1 there are three files          >
           <required for each added molecular radiator.                >

     ADDING  CO AS RADIATOR
     INPUT LINKING FILE
{COLINK.DAT}
     INPUT STATES FILE
{COSTAT.DAT}
     INPUT BAND FILE
{COBAND.DAT}

           <Current values are re-displayed.                           >
      CURRENTLY THERE ARE  2 RADIATORS
      EACH MOLECULAR RADIATOR REQUIRES THREE INPUT DATA SETS
```

```
AFGL#  MOLECULE   LINKING FILE   STATES FILE  BAND FILE
  1       H2O       H2OLINK.DAT    H2OSTAT.DAT  H2OBAND.DAT
  5       CO        COLINK.DAT     COSTAT.DAT   COBAND.DAT

  TO ADD SPECIES INPUT THE AFGL #
  TO REMOVE SPECIES INPUT THE NEGATIVE AFGL #
  PLEASE INPUT ONE CHANGE AT A TIME.
  TYPE 0 TO RETURN TO MAIN MENU
{0}
        <Return to main menu.                                       >

REVIEW OR MODIFY INPUT PARAMETERS

1. TITLE FOR CALCULATION*
2. MODEL ATMOSPHERE
3. NEMESIS CONTROL PARAMETERS
4. MOLECULAR EMITTERS*
5. SOLAR ZENITH ANGLE
6. POPULATION FILE*
7. LOS GEOMETRY*
8. SPECTRAL INTERVAL AND RESOLUTION*
9. OUTPUT DATA*
* OPTIONS CAN BE CHANGED WHILE USING OLD POPULATION FILES

10. UPDATE DEFAULT FILE AND EXIT FOR BATCH EXECUTION
11. EXIT WITH NO UPDATE OF DEFAULT FILE

ENTER # OF ITEM TO BE CHANGED
0 TO CONTINUE SHARC EXECUTION
{2}
        <Enter a 2 to review and/or change the model atmosphere.    >

2.0 REVIEW OR MODIFY INPUT MODEL ATMOSPHERE...

   CURRENT VALUES ARE:
1. ATMOSPHERE #2 CALLED SAT15AN.DAT
2. EXO-ATMOSPHERIC TEMPERATURE (K):  1000.0
3. NIGHT OR DAYTIME:  NIGHT

ENTER # OF ITEM TO BE CHANGED
0 TO CONTINUE
{1}
        <We wish to change to the 1976 standard atmosphere model    >
        <provided with SHARC.                                       >

POSSIBLE ATMOSPHERES :
1.  1976 STANDARD
2.  15 DEG. ANNUAL
3.  30 DEG. SUMMER
4.  30 DEG. WINTER
5.  45 DEG. SPRING/FALL
6.  45 DEG. SUMMER
7.  45 DEG. WINTER
8.  60 DEG. SUMMER
9.  60 DEG. WINTER
```

```
    10.  USER DEFINED ATMOSPHERE
     SELECT ATMOSPHERE :
{1}

        CURRENT VALUES ARE:
     1. ATMOSPHERE #1 CALLED SAT1976.DAT
     2. EXO-ATMOSPHERIC TEMPERATURE (K):  1000.0
     3. NIGHT OR DAYTIME:  NIGHT

     ENTER # OF ITEM TO BE CHANGED
     0 TO CONTINUE
{0}
           <The other two parameters are already what we want, so we    >
           <return to the main menu.                                    >

     REVIEW OR MODIFY INPUT PARAMETERS

     1. TITLE FOR CALCULATION*
     2. MODEL ATMOSPHERE
     3. NEMESIS CONTROL PARAMETERS
     4. MOLECULAR EMITTERS*
     5. SOLAR ZENITH ANGLE
     6. POPULATION FILE*
     7. LOS GEOMETRY*
     8. SPECTRAL INTERVAL AND RESOLUTION*
     9. OUTPUT DATA*
    * OPTIONS CAN BE CHANGED WHILE USING OLD POPULATION FILES

    10. UPDATE DEFAULT FILE AND EXIT FOR BATCH EXECUTION
    11. EXIT WITH NO UPDATE OF DEFAULT FILE

     ENTER # OF ITEM TO BE CHANGED
     0 TO CONTINUE SHARC EXECUTION
{3}
           <Next we wish to review the NEMESIS parameters to insure     >
           <that the sunlight is turned off and that earthshine is      >
           <turned on.  We entered a 3.                                 >

     3.0 REVIEW OR MODIFY NEMESIS INPUTS...

        CURRENT VALUES ARE:
     1. NUMBER OF TRIAL PHOTONS :        10000
     2. MAXIMUM ORDER OF SCATTERING :      100
     3. SUNLIGHT (0=NO , 1=YES) :            0
     4. EARTHSHINE (0=NO , 1=YES) :          0
     ENTER # OF ITEM TO BE CHANGED
     0 TO CONTINUE
{4}
           <Sunlight is turned off, which is correct for our new        >
           <nighttime run.  Earthshine is also currently turned off,    >
           <so we will turn on earthshine.                              >

     DO YOU WANT EARTHSHINE ?
     INPUT 1 FOR YES, OR 0 FOR NO
{1}
```

```
           CURRENT VALUES ARE:
        1. NUMBER OF TRIAL PHOTONS :          10000
        2. MAXIMUM ORDER OF SCATTERING :        100
        3. SUNLIGHT (0=NO , 1=YES) :              0
        4. EARTHSHINE (0=NO , 1=YES) :            1

        ENTER # OF ITEM TO BE CHANGED
        0 TO CONTINUE
{0}
              <Return to main menu.                                    >

        REVIEW OR MODIFY INPUT PARAMETERS

        1. TITLE FOR CALCULATION*
        2. MODEL ATMOSPHERE
        3. NEMESIS CONTROL PARAMETERS
        4. MOLECULAR EMITTERS*
        5. SOLAR ZENITH ANGLE
        6. POPULATION FILE*
        7. LOS GEOMETRY*
        8. SPECTRAL INTERVAL AND RESOLUTION*
        9. OUTPUT DATA*
       * OPTIONS CAN BE CHANGED WHILE USING OLD POPULATION FILES

       10. UPDATE DEFAULT FILE AND EXIT FOR BATCH EXECUTION
       11. EXIT WITH NO UPDATE OF DEFAULT FILE

        ENTER # OF ITEM TO BE CHANGED
        0 TO CONTINUE SHARC EXECUTION
{6}
              <This calculation will be the first in a series of       >
              <calculations based on the same atmosphere.  Therefore,  >
              <the user wants to save the population information to    >
              <reuse in future calculations.                           >
              <To do this the user selects submenu number 6.           >

        6.0 REVIEW OR MODIFY POPULATION FILE NAME:

            CURRENT VALUES ARE:
         1. POPULATION FILE NAME IS = OLDPOP.DAT
         2. POPULATION FILE STATUS = OLD FILE
        INPUT : 0 TO KEEP CURRENT NAME AND STATUS
                1 TO INPUT NEW NAME
                2 TO CHANGE STATUS OF FILE
{1}

        INPUT NAME: (MAXIMUM OF 20 CHARACTERS)
{NEWPOP.DAT}

            CURRENT VALUES ARE:
         1. POPULATION FILE NAME IS = NEWPOP.DAT
         2. POPULATION FILE STATUS = OLD FILE

        INPUT : 0 TO KEEP CURRENT NAME AND STATUS
                1 TO INPUT NEW NAME
```

```
            2 TO CHANGE STATUS OF FILE
{2}

    INPUT STATUS OF FILE (0=NEW) OR (1=OLD)
{0}

        CURRENT VALUES ARE:
      1. POPULATION FILE NAME IS = NEWPOP.DAT
      2. POPULATION FILE STATUS = NEW FILE

    INPUT : 0 TO KEEP CURRENT NAME AND STATUS
            1 TO INPUT NEW NAME
            2 TO CHANGE STATUS OF FILE
{0}
          <Return to main menu.                                      >


    REVIEW OR MODIFY INPUT PARAMETERS

    1. TITLE FOR CALCULATION*
    2. MODEL ATMOSPHERE
    3. NEMESIS CONTROL PARAMETERS
    4. MOLECULAR EMITTERS*
    5. SOLAR ZENITH ANGLE
    6. POPULATION FILE*
    7. LOS GEOMETRY*
    8. SPECTRAL INTERVAL AND RESOLUTION*
    9. OUTPUT DATA*
   * OPTIONS CAN BE CHANGED WHILE USING OLD POPULATION FILES

   10. UPDATE DEFAULT FILE AND EXIT FOR BATCH EXECUTION
   11. EXIT WITH NO UPDATE OF DEFAULT FILE

    ENTER # OF ITEM TO BE CHANGED
    0 TO CONTINUE SHARC EXECUTION
{7}

          <Now to change the LOS geometry to a limb viewing geometry >
          <with a 120 km tangent height.                             >

    7.0 REVIEW OR MODIFY LINE-OF-SIGHT GEOMETRY...

    CURRENT VALUES ARE:

    TANGENT HEIGHT:  60 KM

    INPUT : 0 TO KEEP CURRENT LOS GEOMETRY
            1 TO CHANGE LOS GEOMETRY
{1}
          <As described in Section 4.4, there are three types of LOS >
          <paths supported.  If the users selects a path type that   >
          <is not supported the submenu will prompt for a new path   >
          <type.                                                     >

    PATH TYPES:
```

```
     2 -- OBSERVER TO SOURCE POINT
     3 -- OBSERVER TO SPACE
     4 -- LIMB VIEWING PATH
     SELECT PATH TYPE (0 TO KEEP CURRENT INFORMATION) :
{5}

     PATH TYPE NOT SUPPORTED, TRY AGAIN

     PATH TYPES:

     2 -- OBSERVER TO SOURCE POINT
     3 -- OBSERVER TO SPACE
     4 -- LIMB VIEWING PATH
     SELECT PATH TYPE (0 TO KEEP CURRENT INFORMATION) :
{4}

     INPUT TANGENT HEIGHT IN KM
{120}
           <The user types in desired tangent height in kilometers.     >

     CURRENT VALUES ARE:

     TANGENT HEIGHT:  120 KM

     INPUT : 0 TO KEEP CURRENT LOS GEOMETRY
             1 TO CHANGE LOS GEOMETRY
{0}
           <Return to main menu.                                        >

     REVIEW OR MODIFY INPUT PARAMETERS

     1. TITLE FOR CALCULATION*
     2. MODEL ATMOSPHERE
     3. NEMESIS CONTROL PARAMETERS
     4. MOLECULAR EMITTERS*
     5. SOLAR ZENITH ANGLE
     6. POPULATION FILE*
     7. LOS GEOMETRY*
     8. SPECTRAL INTERVAL AND RESOLUTION*
     9. OUTPUT DATA*
    * OPTIONS CAN BE CHANGED WHILE USING OLD POPULATION FILES

    10. UPDATE DEFAULT FILE AND EXIT FOR BATCH EXECUTION
    11. EXIT WITH NO UPDATE OF DEFAULT FILE

     ENTER # OF ITEM TO BE CHANGED
     0 TO CONTINUE SHARC EXECUTION
{8}
           <This submenu will allow the user to change or modify the    >
           <spectral range and spectral resolution.  These parameters   >
           <are described in more detail in Section 4.4.3.              >

     8.0 REVIEW OR MODIFY SPECTRAL INPUTS...
```

```
        CURRENT VALUES ARE:
     1. MINIMUM WAVENUMBER :   250.0
     2. MAXIMUM WAVENUMBER :   1000.0
     3. SPECTRAL RESOLUTION (MINIMUM OF .1 1/cm) :   1.0
     4. RELAYERING OF ATMOSPHERE FOR OPTICALLY THIN LINES : 0
        1 FOR YES, 0 FOR NO

     ENTER # OF ITEM TO BE CHANGED
     0 TO CONTINUE
{2}

     INPUT MAXIMUM OF SPECTRAL INTERVAL IN WAVENUMBERS :
{2300}

        CURRENT VALUES ARE:
     1. MINIMUM WAVENUMBER :   250.0
     2. MAXIMUM WAVENUMBER :   2300.0
     3. SPECTRAL RESOLUTION (MINIMUM OF .1 1/cm) :   1.0
     4. RELAYERING OF ATMOSPHERE FOR OPTICALLY THIN LINES : 0
        1 FOR YES, 0 FOR NO

     ENTER # OF ITEM TO BE CHANGED
     0 TO CONTINUE
{0}
           <Return to main menu.                                   >
     REVIEW OR MODIFY INPUT PARAMETERS

     1. TITLE FOR CALCULATION*
     2. MODEL ATMOSPHERE
     3. NEMESIS CONTROL PARAMETERS
     4. MOLECULAR EMITTERS*
     5. SOLAR ZENITH ANGLE
     6. POPULATION FILE*
     7. LOS GEOMETRY*
     8. SPECTRAL INTERVAL AND RESOLUTION*
     9. OUTPUT DATA*
    * OPTIONS CAN BE CHANGED WHILE USING OLD POPULATION FILES

    10. UPDATE DEFAULT FILE AND EXIT FOR BATCH EXECUTION
    11. EXIT WITH NO UPDATE OF DEFAULT FILE

     ENTER # OF ITEM TO BE CHANGED
     0 TO CONTINUE SHARC EXECUTION
{9}
           <There is a detailed discussion in Section 5.3 of the   >
           <possible output details obtained by selecting low and  >
           <high values for the above options.  Note some options  >
           <are not currently used.                                >

     9.0 REVIEW OR MODIFY OUTPUT DESIRED...'

         IWRITE VALUES RANGE FROM 0 TO 2'
         LOW VALUES DECREASE THE AMOUNT OF OUTPUT'
         HIGH VALUES INCLUDE ALL OUTPUT FROM LOWER VALUES'
         FOR EXAMPLE: IWRITE=2 WOULD INCLUDE IWRITE=1 OUTPUT'
```

```
         CURRENT VALUES ARE:
      1. MODEL ATMOSPHERE OUTPUT:                    0
      2. ATMOSPHERIC MOLECULE IDENTIFICATION:        0
      3. MOLECULAR RADIATORS AND FILE NAMES:         0
      5. SELECTED TRANSITIONS:                       0
      6. MOLECULAR BAND INFORMATION:                 0
      7. NEMESIS OUTPUT:                             0
      8. FINAL EXCITED STATE POPULATIONS:            0
      9. EXCITED STATE VIBRATIONAL TEMPERATURES:     0
     10. LINE-OF-SIGHT OUTPUT:                       0
     12. SPECTRAL RADIANCE OUTPUT:                   0

      ENTER # OF ITEM TO BE CHANGED
      0 TO CONTINUE
            <In its current state very little output would be saved in  >
            <this calculation.  To print out the model atmosphere one    >
            <would provide a new value for option 1.  Start by           >
            <selecting 1.                                                 >

{1}

      MODEL ATMOSPHERE OUTPUT:'
      INPUT: 0 FOR ATMOSPHERE NAME ONLY'
      INPUT: 1 FOR NAME AND LISTING OF ATMOSPHERE'
{1}
            <Now the atmospheric profile will be saved in the general   >
            <output file.  All of the options have at least two levels  >
            <of available output detail.                                 >

         CURRENT VALUES ARE:
      1. MODEL ATMOSPHERE OUTPUT:                    1
      2. ATMOSPHERIC MOLECULE IDENTIFICATION:        0
      3. MOLECULAR RADIATORS AND FILE NAMES:         0
      5. SELECTED TRANSITIONS:                       0
      6. MOLECULAR BAND INFORMATION:                 0
      7. NEMESIS OUTPUT:                             0
      8. FINAL EXCITED STATE POPULATIONS:            0
      9. EXCITED STATE VIBRATIONAL TEMPERATURES:     0
     10. LINE-OF-SIGHT OUTPUT:                       0
     12. SPECTRAL RADIANCE OUTPUT:                   0

      ENTER # OF ITEM TO BE CHANGED
      0 TO CONTINUE
{9}

      EXCITED STATE VIBRATIONAL TEMPERATURES
      INPUT: 0 FOR NO OUTPUT
      INPUT: 1 FOR EXCITED STATE VIBRATIONAL TEMPERATURES
{1}
            <Now the vibrational temperatures for the excited state     >
            <species will be saved in the general output file.           >

         CURRENT VALUES ARE:
      1. MODEL ATMOSPHERE OUTPUT:                    1
      2. ATMOSPHERIC MOLECULE IDENTIFICATION:        0
```

```
     3. MOLECULAR RADIATORS AND FILE NAMES:       0
     5. SELECTED TRANSITIONS:                     0
     6. MOLECULAR BAND INFORMATION:               0
     7. NEMESIS OUTPUT:                           0
     8. FINAL EXCITED STATE POPULATIONS:          0
     9. EXCITED STATE VIBRATIONAL TEMPERATURES:   1
    10. LINE-OF-SIGHT OUTPUT:                     0
    12. SPECTRAL RADIANCE OUTPUT:                 0

     ENTER # OF ITEM TO BE CHANGED
     0 TO CONTINUE
{0}
           <Return to main menu.                                      >

     REVIEW OR MODIFY INPUT PARAMETERS

     1. TITLE FOR CALCULATION*
     2. MODEL ATMOSPHERE
     3. NEMESIS CONTROL PARAMETERS
     4. MOLECULAR EMITTERS*
     5. SOLAR ZENITH ANGLE
     6. POPULATION FILE*
     7. LOS GEOMETRY*
     8. SPECTRAL INTERVAL AND RESOLUTION*
     9. OUTPUT DATA*
    * OPTIONS CAN BE CHANGED WHILE USING OLD POPULATION FILES

    10. UPDATE DEFAULT FILE AND EXIT FOR BATCH EXECUTION
    11. EXIT WITH NO UPDATE OF DEFAULT FILE

     ENTER # OF ITEM TO BE CHANGED
     0 TO CONTINUE SHARC EXECUTION
{10}

     SHARC READY FOR BATCH RUN

           <Session completed.  Now the user has prepared the new     >
           <SHARC.INP file shown in Table 12 for use in a batch or    >
           <background calculation.                                   >
```

TABLE 11. SAMPLE SHARC.INP FILE.

```
C0 FILE SHARC.INP
C0 THIS FILE HOLDS THE DEFAULT VALUES FOR SHARC
C0 THIS FILE IS UPDATED TO THE CURRENT VALUES OF THE PARAMETERS
C0 EACH TIME SHARC IS RUN.
C0
C1 THE FIRST LINE CONTAINS THE INTERACTIVE/BATCH OPTION
C1 IF IT EQUALS 1, SHARC WILL RUN INTERACTIVELY, ALLOWING
C1 THE USER TO UPDATE OPTIONS.  IF IT EQUALS 0, SHARC WILL
C1 RUN IN BATCH MODE.  THIS PARAMETER IS SET TO 1 AFTER A
```

```
C1 SUCCESSFUL SHARC RUN.
C1 FORMAT = I4
C1##
   1
C2 TITLE FOR CALCULATION   WILL APPEAR ON TOP OF GENERAL OUTPUT FILE
C2 FORMAT(1X,A68,I3)
C#################################################################### ###
 OLD TEST CASE                                                        13
C3 LINE 2 CONTAINS THE VARIABLE IATMOS.
C3 THIS VARIABLE IS USED TO SELECT THE DESIRED MODEL ATMOSPHERE AND
C3 THE ATMOSPHERIC FILE NAME.
C3 FORMAT = I4,2X,A11
C3##  ###########
   2  SAT15AN.DAT
C4 LINE 3 CONTAINS THE EXO-ATMOSPHERIC TEMPERATURE AND
C4 A CONTROL PARAMETER WHICH SELECTS EITHER THE DAY OR NIGHT
C4 OPTION FOR THE MODEL ATMOSPHERE.
C4 FORMAT = E12.5,2X,A5
C4 #####E+##  #####
  .10000E+04  NIGHT
C5 NEMESIS CONTROL PARAMETERS
C5 WARNING: CHANGING THESE PARAMETERS WILL EFFECT THE ACCURACY
C5 OF THE MONTE CARLO SIMULATION.
C5 TOTAL NUMBER OF PHOTONS, MAXIMUM ORDER OF SCATTERING
C5 GLOBAL SUNSHINE AND EARTHSHINE PARAMETERS (1=YES , 0=NO)
C5 FORMAT=2X,6I,2X,6I,2x,I6,2X,I6
C5 #####  ######  ######  ######
   10000     200      0      0
C6 AFGL# FOR MOLECULE,LINKING FILE, STATE FILE, BAND FILE
C6 UP TO 5 RADIATORS H2O=1, CO2=2, O3=3, CO=5, NO=8
C6FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C6####  ###########  ###########  ###########
     1  H2OLINK.DAT  H2OSTAT.DAT  H2OBAND.DAT
C7 FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C7####  ###########  ###########  ###########
     0
C8 FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C8 ###  ###########  ###########  ###########
     0
C9 FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C9 ###  ###########  ###########  ###########
     0
C10FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C10###  ###########  ###########  ###########
     0
C11 SOLAR ZENITH ANGLE IN DEGREES. 0 FOR THE SUN OVERHEAD
C11( 0.0 WHEN THE SUN IS OVERHEAD) THIS OPTION IS USED FOR DAYLIGHT ONLY
C11FORMAT = E12.5
C#.#####E+##
  .00000E+02
C12NEXT 6 LINES CONTAIN LOS GEOMETRY INFORMATION
C12LINE 12 CONTAINS   ATH AND ICASE
C12FORMAT = I',2X,
C12#  ####
   4     3
```

```
C13LINE 13 CONTAINS H1ALT, H1LONG AND H1LAT
C13FORMAT = 3(E12.7,2X)
C13#####E+##  .#######E+##  .#######E+##
.6100000E+02  .4500000E+02  .4500000E+02
C14LINE 14 CONTAINS H2ALT, H2LONG AND H2LAT
C14FORMAT = 3(E12.7,2X)
C14#####E+##  .#######E+##  .#######E+##
.6100000E+02  .1000000E+02  .1000000E+02
C15LINE 15 CONTAINS RANGE,BETA,A0
C15FORMAT = 3(E13.8,1x)
C15######E+## .########E+## .########E+##
 .6000000E+02  .1200000E+03  .0000000E+00
C16LINE 16 CONTAINS B0,HMIN,LEN
C16FORMAT = 2(E13.8,1x),I4
C16######E+## .########E+## ####
 .9000000E+02  .6000000E+02    0
C17Line 17 CONTAINS TIME,IDAY,ICASES
C17TIME IS GMT TIME (0. TO 24.)
C17IDAY IS FROM 1 TO 366
C17THESE OPTIONS ARE NOT USED IN SHARC-1
C17FORMAT = E12.7,2X,2I4
C17#####E+##  #### ###
.0000000E+00     6   1
C18SPECTRAL INFORMATION IN CM-1
C18 WMIN,WMAX,BINRES(RESOLUTION),IRELAY=1 FOR RELAYERING
C18FORMAT = 2X,3(E12.5,2X),I2,2X,E12.5
C18#.#####E+##  ##.#####E+##  ##.#####E+##  ##
    .25000E+03    .10000E+04    .10000E+01   0
C19 OUTPUT CONTROL PARAMETERS:
C19 1) MODEL ATMOSPHERE OUTPUT ==>1 FOR FULL LISTING
C19 2) ATMOSPHERIC MOLECULE IDENTIFICATION == >2 FOR TABLE
C19 3) MOLECULAR RADIATORS INFORMATION ==>2 FOR ECHO OF INPUTS
C19 4) NOT CURRENTLY USED
C19 5) SELECTED TRANSITIONS ==>1 FOR TRANSITIONS SELECTED
C19 6) MOLECULAR BAND INFORMATION ==>2 FOR ECHO OF BAND INFORMATION
C19 7) NEMESIS OUTPUT ==>1 NEMESIS ONLY ==2 FOR POST POPULATIONS
C19 8) FINAL STATE POPULATIONS ==>1 YES
C19 9) FINAL VIBRATIONAL TEMPERATURES ==>1 YES
C19 10)LOS OUTPUT ==>1 FOR COLUMN DENSITIES
C19 11)CURRENTLY NOT USED
C19 12)SPECTRAL RADIANCE OUTPUT ==>1 FOR RADIANCE OUTPUT IN GENERAL
C19    OUTPUT FILE  SPECTRAL INFORMATION IS ALWAYS PLACED IN SPEC.OUT
C19 FORMAT = 12(2X,I2)
C  1   2   3   4   5   6   7   8   9  10  11  12
C ##  ##  ##  ##  ##  ##  ##  ##  ##  ##  ##  ##
   0   0   0   0   0   0   0   0   0   0   0   0
C20 SAVED POPULATIONS FILE NAME AND ISAVE
C20 WHEN ISAVE = 0 POPULATIONS ARE SAVED
C20 ISAVE = 1 SAVED POPULATIONS ARE USED FOR CALCULATION
C20 FORMAT=(2X,A20,2X,I4)
C2####################  ####
  OLDPOP.DAT              1
```

TABLE 12. UPDATED SHARC.INP FILE.

```
C0 FILE SHARC.INP
C0 THIS FILE HOLDS THE DEFAULT VALUES FOR SHARC
C0 THIS FILE IS UPDATED TO THE CURRENT VALUES OF THE PARAMETERS
C0 EACH TIME SHARC IS RUN.
C0
C1 THE FIRST LINE CONTAINS THE INTERACTIVE/BATCH OPTION
C1 IF IT EQUALS 1, SHARC WILL RUN INTERACTIVELY, ALLOWING
C1 THE USER TO UPDATE OPTIONS.  IF IT EQUALS 0, SHARC WILL
C1 RUN IN BATCH MODE.  THIS PARAMETER IS SET TO 1 AFTER A
C1 SUCCESSFUL SHARC RUN.
C1 FORMAT = I4
C1##
   0
C2 TITLE FOR CALCULATION   WILL APPEAR ON TOP OF GENERAL OUTPUT FILE
C2 FORMAT(1X,A68,I3)
C#################################################################### ###
 NEW TEST CASE                                                          13
C3 LINE 2 CONTAINS THE VARIABLE IATMOS.
C3 THIS VARIABLE IS USED TO SELECT THE DESIRED MODEL ATMOSPHERE AND
C3 THE ATMOSPHERIC FILE NAME.
C3 FORMAT = I4,2X,A11
C3##  ###########
   1  SAT1976.DAT
C4 LINE 3 CONTAINS THE EXO-ATMOSPHERIC TEMPERATURE AND
C4 A CONTROL PARAMETER WHICH SELECTS EITHER THE DAY OR NIGHT
C4 OPTION FOR THE MODEL ATMOSPHERE.
C4 FORMAT = E12.5,2X,A5
C4 ######E+##  #####
  .10000E+04  NIGHT
C5 NEMESIS CONTROL PARAMETERS
C5 WARNING: CHANGING THESE PARAMETERS WILL EFFECT THE ACCURACY
C5 OF THE MONTE CARLO SIMULATION.
C5 TOTAL NUMBER OF PHOTONS, MAXIMUM ORDER OF SCATTERING
C5 GLOBAL SUNSHINE AND EARTHSHINE PARAMETERS (1=YES , 0=NO)
C5 FORMAT=2X,6I,2X,6I,2x,I6,2X,I6
C5 #####  ######  ######  ######
   10000      200      0       1
C6 AFGL# FOR MOLECULE,LINKING FILE, STATE FILE, BAND FILE
C6 UP TO 5 RADIATORS H2O=1, CO2=2, O3=3, CO=5, NO=8
C6FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C6####  ###########  ###########  ###########
     1  H2OLINK.DAT  H2OSTAT.DAT  H2OBAND.DAT
C7 FORMAT=2X,I4.2X,11A1,2X,11A1,2X,11A1
C7####  ###########  ###########  ###########
     5  COLINK.DAT   COSTAT.DAT   COBAND.DAT
C8 FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C8 ###  ###########  ###########  ###########
     0
C9 FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C9 ###  ###########  ###########  ###########
```

```
    0
C10FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C10###  ###########  ###########  ###########
    0
C11 SOLAR ZENITH ANGLE IN DEGREES. 0 FOR THE SUN OVERHEAD
C11( 0.0 WHEN THE SUN IS OVERHEAD) THIS OPTION IS USED FOR DAYLIGHT ONLY
C11FORMAT = E12.5
C#.#####E+##
  .00000E+02
C12NEXT 6 LINES CONTAIN LOS GEOMETRY INFORMATION
C12LINE 12 CONTAINS IPATH AND ICASE
C12FORMAT = I4,2X,I4
C12#  ####
   4    3
C13LINE 13 CONTAINS H1ALT, H1LONG AND H1LAT
C13FORMAT = 3(E12.7,2X)
C13#####E+##  .#######E+##  .#######E+##
.6100000E+02  .4500000E+02  .4500000E+02
C14LINE 14 CONTAINS H2ALT, H2LONG AND H2LAT
C14FORMAT = 3(E12.7,2X)
C14#####E+##  .#######E+##  .#######E+##
.6100000E+02  .1000000E+02  .1000000E+02
C15LINE 15 CONTAINS RANGE,BETA,A0
C15FORMAT = 3(E13.8,1x)
C15######E+## .########E+## .########E+##
 .6000000E+02  .1200000E+03  .0000000E+00
C16LINE 16 CONTAINS B0,HMIN,LEN
C16FORMAT = 2(E13.8,1x),I4
C16######E+## .########E+## ####
 .9000000E+02  .1200000E+03    0
C17Line 17 CONTAINS TIME,IDAY,ICASES
C17TIME IS GMT TIME (0. TO 24.)
C17IDAY IS FROM 1 TO 366
C17THESE OPTIONS ARE NOT USED IN SHARC-1
C17FORMAT = E12.7,2X,2I4
C17#####E+##  #### ###
.0000000E+00     6   1
C18SPECTRAL INFORMATION IN CM-1
C18 WMIN,WMAX,BINRES(RESOLUTION),IRELAY=1 FOR RELAYERING
C18FORMAT = 2X,3(E12.5,2X),I2,2X,E12.5
C18#.#####E+##  ##.#####E+##  ##.#####E+##  ##
    .25000E+03    .23000E+04    .10000E+01   0
C19 OUTPUT CONTROL PARAMETERS:
C19 1) MODEL ATMOSPHERE OUTPUT ==>1 FOR FULL LISTING
C19 2) ATMOSPHERIC MOLECULE IDENTIFICATION == >2 FOR TABLE
C19 3) MOLECULAR RADIATORS INFORMATION ==>2 FOR ECHO OF INPUTS
C19 4) NOT CURRENTLY USED
C19 5) SELECTED TRANSITIONS ==>1 FOR TRANSITIONS SELECTED
C19 6) MOLECULAR BAND INFORMATION ==>2 FOR ECHO OF BAND INFORMATION
C19 7) NEMESIS OUTPUT ==>1 NEMESIS ONLY ==2 FOR POST POPULATIONS
C19 8) FINAL STATE POPULATIONS ==>1 YES
C19 9) FINAL VIBRATIONAL TEMPERATURES ==>1 YES
C19 10)LOS OUTPUT ==>1 FOR COLUMN DENSITIES
C19 11)CURRENTLY NOT USED
C19 12)SPECTRAL RADIANCE OUTPUT ==>1 FOR RADIANCE OUTPUT IN GENERAL
```

```
C19    OUTPUT FILE  SPECTRAL INFORMATION IS ALWAYS PLACED IN SPEC.OUT
C19 FORMAT = 12(2X,I2)
C  1   2   3   4   5   6   7   8   9  10  11  12
C ##  ##  ##  ##  ##  ##  ##  ##  ##  ##  ##  ##
   1   0   0   0   0   0   0   0   1   0   0   0
C20 SAVED POPULATIONS FILE NAME AND ISAVE
C20 WHEN ISAVE = 0 POPULATIONS ARE SAVED
C20 ISAVE = 1 SAVED POPULATIONS ARE USED FOR CALCULATION
C20 FORMAT=(2X,A20,2X,I4)
C2####################  ####
  NEWPOP.DAT               0
```

4.3 Definition of Input Variables

The input parameters are read from the input file called SHARC.INP and are stored internally in a character*72 array called DFLTS. These parameters may be changed in SHARC.INP by editing the file directly, or by using the interactive input module. Parameters in SHARC.INP are written and read with fixed FORMAT. The required FORMATS and other comments are listed above the input data in SHARC.INP. Two example SHARC.INP files are shown in the previous section in Tables 10 and 11. There are 20 lines of actual input data in SHARC.INP. The input parameters on these lines are shown below.

LINE 1:	Interactive/Batch	Format:I4
ACTIVE	= 0	Skip interactive module
	1	Run interactively
		Note: ACTIVE is set to 1 after a successful SHARC run.

LINE 2:	Title Card	Format:1X,A68,I3
TITLE		Title for this run
NTIT		Number of characters in TITLE

LINE 3:	Atmospheric Model	Format:I4,2X,A11
IATMOS		Atmosphere number
ATNAME		Name of model atmosphere

LINE 4:	Atmospheric Parameters	Format:E12.5,2x,A5	
EXOTMP		Exo-atmospheric temperature	
NGHTDY	NIGHT	Nighttime	
	DAY	Daytime	

LINE 5:	NEMESIS Parameters	Format:2X,I6,2X,I6,2X,I6,2X,I6	
NPHOT		Total number of photons	
NORDER		Maximum order of scattering	
ISUN	= 0	No incident sunshine	
	1	Include solar pumping	
IEARTH	= 0	No upwelling earthshine	
	1	Include earthshine pumping	

Warning: Changing these parameters affects the accuracy of the Monte Carlo simulation. The Nemesis parameters are discussed in Section 4.4.1

LINE 6-10:	Molecular Radiators	Format:2X,I4,2X,11A1,2X,11A1,2X,11A1	
IRAD	= 0	No radiator	
	1	H_2O	Note: These follow the HITRAN identification numbers.
	2	CO_2	
	3	O_3	
	5	CO	
	8	NO	
MOLNAM(1)		Name of linking file, e.g., O3LINK.DAT (IRAD=3)	
MOLNAM(2)		Name of state file, e.g., O3STAT.DAT (IRAD=3)	
MOLNAM(3)		Name of band file, e.g., O3BAND.DAT (IRAD=3)	

LINE 11:	Solar Direction	Format:E12.5	
SOLANG(deg)		Solar zenith angle	

LINE 12:	Observer Path	Format:I4,2X,I4	
IPATH	=2	Observer to specified point	
	3	Observer to space	
	4	Limb viewing from space	
ICASE		Determines LOS input parameter sequences NOTE: The geometry parameters are	

discussed in greater detail in Section 4.4.2

LINE 13:	Observer Parameters		Format:3(E12.7,2X)
HlALT (km)		Observer altitude	
HlLONG(deg)		" longitude	
HlLAT (deg)		" latitude	
LINE 14:	Source Parameters		Format:3(E12.7,2X)
H2ALT (km)		Source (or target) altitude	
H2LONG(deg)		" longitude	
H2LAT (deg)		" latitude	
LINE 15:	Other Path Parameters		Format:3(E13.8,1X)
RANGE (km)		Range	
BETA (deg)		Earth center angle subtended by path	
A0 (deg)		Path zenith angle at observer	
LINE 16:	Other Path Parameters		Format:3(E13.8,1X)
BO (deg)		Path azimuthal angle	
HMIN (km)		Minimum altitude for limb path	
LEN	= 0 1	Short downward limb path Long " " "	
LINE 17:	Additional Parameters		Format:E12.7,2X,I4
	NOTE: These parameters are not used in this version of SHARC		
TIME		Greenwich Mean Time	
IDAY		Day of the year (1 to 366)	
ICASES		Determines solar input parameter sequences	
LINE 18:	Spectral Parameters		Format:2X,3(E12.5,2X),I2,2X,E12.5
WMIN (cm^{-1})		Minimum Wavenumber for Calculation	
WMAX (cm^{-1})		Maximum Wavenumber for Calculation	

BINRES(cm^{-1}) Resolution

IRELAY =0 No Relayering
1 Relayer atmosphere for radiance calculation of optically thin lines. This option is detailed in Section 4.4.3

LINE 19: Output Parameters Format:12(2X,I2)

IWRITE(1-12) =0 Minimal output
1 Recommended output
2 Debugging output
NOTE: Section 5.2 details the output options which can be selected for the 12 IWRITE's

LINE 20: Population File Format:2X,A20,2X,I4

POPNAM Name of population file

ISAVE =0 POPNAM is new file
1 POPNAM is old file

4.4 Detailed Parameter Discussion

This section defines the input parameters for the NEMESIS, GEOMETRY, and SPCRAD modules. *The NEMESIS control parameters warrant further description* since the accuracy of the Monte Carlo simulation depends upon their values. The Geometry parameters section will describe the various subsets of geometry variables needed to define a LOS. The relayering option is discussed in the SPCRAD parameter section.

4.4.1 NEMESIS Parameters

The NEMESIS module determines the enhancement of the atmospheric excited states layer populations due to layer radiative self-trapping and layer-layer radiative pumping. The module determines the first-order population enhancement using a Monte Carlo simulation of the initial source photon emission and absorption or escape. The number of photons, NPHOT, determines the statistical uncertainty of the Monte Carlo calculation. Changing this variable to a small number saves computer time, but causes large statistical uncertainties. For reasonable statistical uncertainties NPHOT should be 10,000 or larger.

The NORDER parameter determines the maximum order of scattering calculated by NEMESIS. Changing this number to less than 100 does not save much computer time since the Monte Carlo simulation is performed for first-order scattering only and higher order scattering is determined recursively. Many orders of scattering may be important for some molecular bands, such as 4.3 μm CO_2 radiation. A value of 100 for NORDER is sufficiently large.

The ISUN and IEARTH parameters turn on/off solar and earthshine pumping. A value of 1 means the pumping is on and a value of 0 means the pumping is off.

4.4.2 Geometry Parameters

The LOS is defined as the straight line which connects the observer located at a point H1 to the source located at H2. Curvature of the LOS due to refraction is negligible over the altitude regime considered in SHARC. Three classes of LOS paths are supported by SHARC and are specified through the variable IPATH:

IPATH = 2 -- observer to source,
= 3 -- observer to space, and
= 4 -- limb viewing.

The nomenclature used in the geometry module is derived from the low-altitude radiance code LOWTRAN 6.[7] In the current SHARC version, there is no IPATH = 1 option. There are a number of geometric parameters that must be specified in order to define each type of path, and these are defined in Table 13 and illustrated in Figure 3. Altitudes and ranges are given in km, and angles in degrees. Longitudes can have values ranging form 0^o to 360^o, and latitudes, from -90^o at the south pole to 90^o at the north pole. A0 is the local zenith angle of the LOS as measured from the vertical line connecting H1 and the earth center. The angle B0 is the azimuth of the LOS as measured in the plane normal to the vertical at the same altitude as the observer (e.g., the local horizontal); it varies from -180^o to 180^o.

TABLE 13. LOS PARAMETERS.

H1ALT	observer altitude
H1LONG	" longitude
H1LAT	" latitude
H2ALT	source altitude
H2LONG	" longitude
H2LAT	" latitude
RANGE	distance from H1 to H2
BETA	earth-center angle between H1 and H2
A0	zenith angle of LOS at observer
B0	LOS azimuthal angle; north = 0 & east = 90^{o}
HMIN	tangent height from the surface of the earth;
LEN	designates short or long paths for certain down-looking geometries

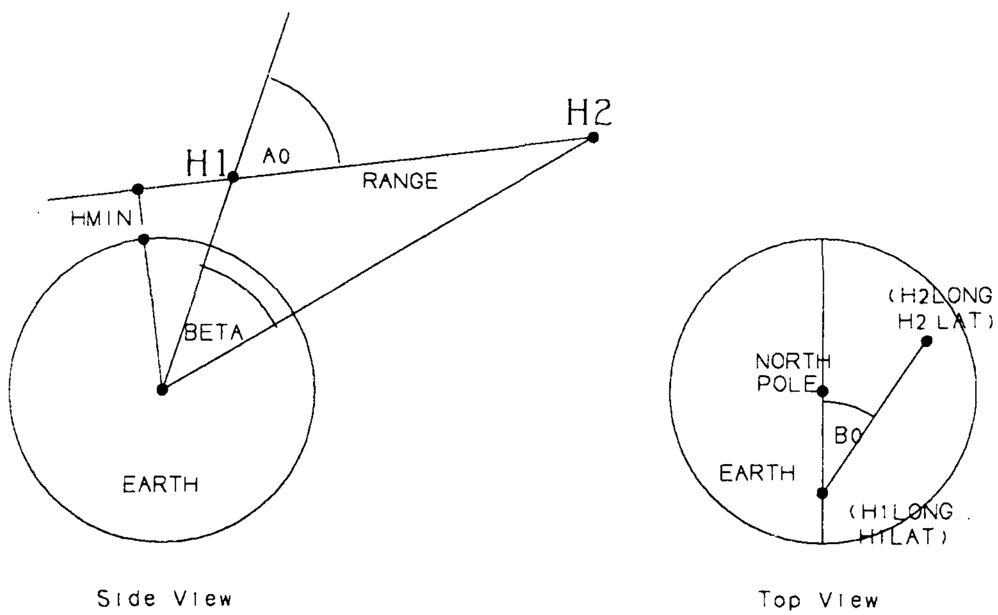

Figure 3. Definitions of LOS Parameters.

The parameters listed in Table 13 overspecify the LOS. For a particular LOS only one of many different subsets is required as input. The other parameters are calculated internally. Each class, designated by its IPATH value, has various options for specifying the LOS. These are labeled by the integer variable ICASE and are listed in Table 14 along with the required geometrical inputs. The particular case with IPATH = 2 and ICASE = 1 is

TABLE 14. GEOMETRY INPUT SEQUENCES.

IPATH	ICASE	Geometrical Inputs
2	1	H1, H2ALT, A0, B0
		H1, H2ALT, A0, B0, LEN
	2	H1, RANGE, A0, B0
	3	H1, H2ALT, RANGE, B0
	4	H1, H2ALT, BETA, B0
	5	H1, H2ALT, H2LONG, H2LAT
3	1	H1, A0, B0
	2	H1, HMIN, B0
4	1	HMIN

Note: 1. H1 stands for (H1ALT, H1LAT, H1LONG).

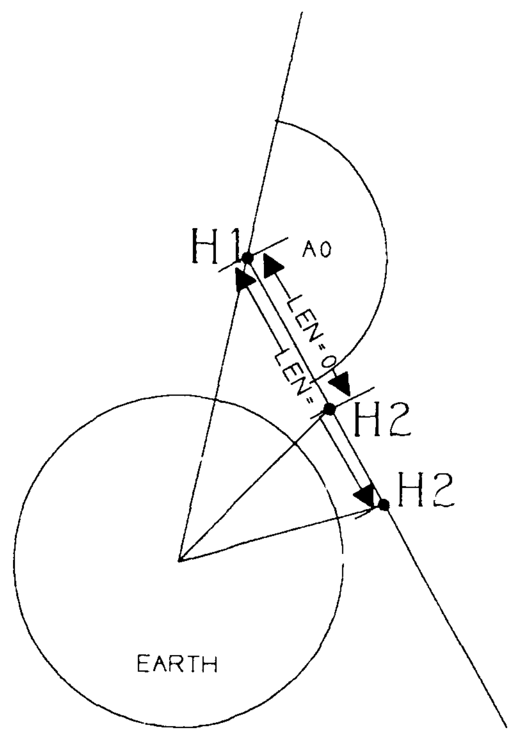

Figure 4. Specification of the LEN Parameter for Down-Looking Paths.

ambiguous when H1 > H2. The two paths are distinguished with the LEN variable and are illustrated in Figure 4.

4.4.3 Spectral Radiance Parameters

The spectral range is defined by inputting the minimum, WMIN, and maximum, WMAX, frequency (cm^{-1}) of interest. SHARC currently includes lines from 250 to 5000 cm^{-1}. The spectral resolution, BINRES, is given in cm^{-1} and is currently limited to 0.1 cm^{-1}. The spectral radiance array can contain 10,000 points. So, if a 0.1 resolution is used only a 1000 cm^{-1} spectral range can be used. The interactive input module will alert the user if the range is too large for the selected resolution, and it will reset WMAX to reduce the range.

The relayering option allows users to save computational time by relayering the model atmosphere for optically thin transitions. The relayering takes adjacent atmospheric layers and combines them into a single larger layer. Care is taken to preserve the total column density and other properties, such as rotational and translational temperatures, are averaged over the combined layers. The SPCRAD module implements the relayering option on a line-by-line basis. A total optical depth estimate is performed and if a line is found to be optically thin and the user has selected relayering, i.e. IRELAY=1, a relayered atmosphere is used. The relayering algorithm reduces n layers to $\sqrt{n}$ layers. Up to an order of magnitude increase in speed can be attained with little loss in accuracy. The total number of lines and the total number of relayered lines are summarized for each band in the general SHARC output file.

5. SHARC OUTPUT FILES

5.1 Error File

The SHARC error file (SHARC.ERR) contains error and warning statements generated during SHARC execution. The majority of error messages are due to improper preparation of the input files. Warning or caution messages usually result from inconsistent use of input files. An error message during execution is considered fatal, and execution will stop after the error message is written to the error file. A warning or caution message is not fatal (i.e., does not terminate execution), but it should inform the user that input files are inconsistent, that only a partial calculation has been performed, or that numerical difficulties have been encountered and fixed in one of the SHARC modules. The user should monitor the error file after each SHARC run to insure that the desired calculation was properly performed.

There are currently 113 different error/caution messages which can be written to the error file during execution. The error/caution messages contain the subroutine name in which the problem occurred. As an example of an error message, consider an error resulting from inconsistent input in the molecular states (see Section 3.2) and bands (see Section 3.3) files. Assume that the 2→1 vibrational transition for CO has been specified in the molecular states file (see Table 5). If the data for the line strength distribution function for the 2→1 transition has not been included in the molecular bands file (see Table 6), the following error message will be written to the error file:

```
ERROR IN BANDIN...
     CO(1)      - CO(0)      BAND MISSING FROM BAND DATA
```

prompting the user to check the CO bands file for an input error or omission of data.

As seen in the previous example, the error/caution messages generated from input files are usually self-explanatory, and the user should be able to easily correct the problem. In some cases, however, the problem may be more subtle. For example, error/caution messages generated during calculation of number densities of vibrationally excited states most likely will require the user to carefully check the chemical kinetics mechanism and the list of transitions considered by NEMESIS.

5.2 General Output File

The general SHARC output file contains a summary of selected output from each module. As mentioned previously, there are three levels of output which can be obtained from each SHARC module. The level (and size) of output is selected through the interactive menu (see Section 4.2). The level of output can be selected independently for several of the SHARC modules. The lowest level contains the minimum amount of information (IWRITE=0) necessary to characterize the calculation, and the highest level contains the maximum amount of information (IWRITE=2). The type of output which is written to the output file for the specified IWRITE option is illustrated in Table 15. Notice that the atmosphere name and the band radiance summary (see Table 15) are always written to the output file, and the spectral radiance as a function of frequency is always written to the plot file (see Section 5.4).

TABLE 15. TYPE OF OUTPUT CONTAINED IN SHARC.OUT FILE.

OUTPUT	OPTION	DESCRIPTION
Model Atmosphere	0	Atmosphere File Name
	1,2	Complete Atmosphere Input File
Atmospheric Molecule ID	0,1	No Output
	2	AFGL Molecular Identification Number for Each Atmospheric Species
Molecular Radiators and File Names	0,1	No Output
	2	List of Selected Molecular Radiators, and Associated File Names for the "Linking", "States", and "Bands" Files
Selected Transitions	0	No Output
	1,2	Complete Molecular States Input File
Molecular Band Data	0,1	No Output
	2	Complete Molecular Bands Input File
NEMESIS Output	0	No Output
	1	Initial Steady State Layer Source Populations and NEMESIS Excited State Population Enhancements; Earthshine, Sunshine, and Atmospheric Excitation Rates; and the quenching/re-emission Probabilities
	2	Post NEMESIS Excited State Populations for Each Selected Transition
Final Excited State Populations	0	No Output
	1,2	Final Excited State Populations
Final Excited State Temperatures	0	No Output
	1,2	Final Excited State Temperatures
Line of Sight Output	0	
	1,2	Species Total Column Densities Along Line of Sight
Band Radiance Summary	-	The Transition, Frequency, Number of Lines for the Transition, and the Band Radiance for the Transition for Each Selected Radiator
Spectral Radiance Output	0	Plot File (SHARC.SPC)
	1,2	Spectral Radiance Table

5.3 Population File

The excited-state populations for each atmospheric layer will change only when a new model atmosphere is used, day and night conditions change or a new solar zenith angle is defined. Thus, the excited-state populations and the information necessary to uniquely characterize them are written to a binary "*population*" *file*. This allows the user to perform multiple SHARC calculations for any number of observer-source scenarios without re-calculating the populations each time. The relevant information written to the "population" file is:

- Date of the excited state population calculation,
- The model atmosphere file (Section 3.5),
- The molecular radiators and the associated "linking", "states", and "bands" files,
- The list of species (Section 3.1) for each molecular radiator,
- The molecular states file (Section 3.2) for each molecular radiator, and
- The excited state populations and associated temperatures for each molecular radiator.

For subsequent calculations using the "population" file, it is necessary to change only the input and output parameters relevant to the GEOMETRY and/or SPCRAD sections of the SHARC.INP file (Section 4.2-4.3). Although the complete set of options described in Section 5.2 for creating the general output file are not available when using a previously created "population" file, the output file does contains sufficient detail to uniquely characterize the "population" file used. However, the user should refer back to the original general output file generated when the population file was created if any greater detail is desired.

5.4 Plot File

An ASCII plot file (SHARC.SPC) is created to allow the user to either plot the calculated spectral radiance directly or to further reduce the data.

For example, the user may wish to apply a specific filter function to the spectral radiance or to convert to a set of units other than those used by SHARC. The plot file contains the frequency (cm^{-1}) and the spectral radiance ($W/sr/cm^2/cm^{-1}$) written as an (x,y) ordered pair with one pair per line.

6. RUNNING THE PLOTTING PACKAGE

The plotting software is a separate package which can be used to plot the SHARC spectral output. The plotting program, which is a general x-y plotting package, is interactive and has two menus of options. First, the program queries the user for the input file name that is to be read and plotted. The default name for the file is SPEC.OUT. This is the name of the spectral output file generated by the SHARC program. The input file is a unformatted list of x,y pairs without any header information. After the input file is read the menu options can be modified for a particular plotting case. The first menu has eight options which can be altered. These include the plot output file name, the titles for the plot and the x and y axes, the plot type, the location of the axis tic marks, and the lengths of the x and y axes. A set of standard default values of these parameters is presented to the user. These default values can be changed or the next menu can be accessed by typing a zero. The second menu allows the dynamic range of the radiance (y axis) and the wavenumber interval (x axis) to be adjusted. Default values are calculated from the input data file which span the entire dynamic range of the radiance and the entire wavenumber interval of the input. Adjustment of the number of major and minor tics on the axis is also an option of the second menu. A session with the plot package is included here to illustrate the interactive nature of the program. User responses are contained in brackets {..} to distinguish them from the program queries. Comments about the program queries and user responses are contained in the brackets <..>.

Begin session:

{run plot}

<An interactive session for plotting a SHARC output spectrum.>
....

```
     THE DEFAULT FILE NAME IS SPEC.OUT
     IS THIS THE FILE YOU WANT PLOTTED? [Y,N]
{N}
          <Responding with a "n" causes the program to request an     >
          <input file.                                                >
```

```
     INPUT THE FILE NAME FOR THE DATA TO BE PLOTTED
{NOSPEC.OUT}
           <The program will now read in data from the disk file       >
           <file NOSPEC.OUT.                                            >

           <The first menu will now be printed on the screen.  Each    >
           <time it is presented it contains the current options.      >
           <Initially it contains default options.  When the           >
           <user is satisfied with the options, a "0" response         >
           <will cause the program to go to the next menu.             >

     THE FOLLOWING VARIABLES HAVE BEEN SELECTED:
     1. Plot output file :OUTPUT.PLT
     2. Plot title       :SHARC SPECTRUM
     3. X-axis label     :WAVENUMBER
     4. Y-axis label     :RADIANCE
     5. Plot type        :SEMI-LOG PLOT (X LINEAR)
     6. Tic marks        :OUTSIDE GRAPH
     7. X-axis length in inches: 5.0
     8. Y-axis length in inches: 5.0

     INPUT ITEM NUMBER TO BE CHANGED OR ZERO TO EXIT
{1}
           <Responding with a "1" causes the program to request a      >
           <new file name for the plot data.                           >


     INPUT THE NAME OF THE PLOT OUTPUT FILE
{NO.PLT}
           <The output plot data will be in file NO.PLT.               >


     THE FOLLOWING VARIABLES HAVE BEEN SELECTED:
     1. Plot output file :NO.PLT
     2. Plot title       :SHARC SPECTRUM
     3. X-axis label     :WAVENUMBER
     4. Y-axis label     :RADIANCE
     5. Plot type        :SEMI-LOG PLOT (X LINEAR)
     6. Tic marks        :OUTSIDE GRAPH
     7. X-axis length in inches: 5.0
     8. Y-axis length in inches: 5.0

     INPUT ITEM NUMBER TO BE CHANGED OR ZERO TO EXIT
{2}
           <Responding with a "2" causes the program to request a new  >
           <title for the plot.                                        >

     INPUT THE PLOT TITLE
{NO 60 km limb}
           <The plot title will now be "NO 60 km limb"                 >

     THE FOLLOWING VARIABLES HAVE BEEN SELECTED:
```

```
     1. Plot output file :NO.PLT
     2. Plot title       :NO 60 km limb
     3. X-axis label     :WAVENUMBER
     4. Y-axis label     :RADIANCE
     5. Plot type        :SEMI-LOG PLOT (X LINEAR)
     6. Tic marks        :OUTSIDE GRAPH
     7. X-axis length in inches: 5.0
     8. Y-axis length in inches: 5.0

     INPUT ITEM NUMBER TO BE CHANGED OR ZERO TO EXIT
{3}
          <Responding with a "3" causes the program to request a new  >
          <label for the x axis.                                      >

     INPUT THE X-AXIS LABEL
{wavenumber (cm^-^1)}
          <The label will now be in lower case and contain units.     >


     THE FOLLOWING VARIABLES HAVE BEEN SELECTED:
     1. Plot output file :NO.PLT
     2. Plot title       :NO 60 km limb
     3. X-axis label     :wavenumber (cm^-^1)
     4. Y-axis label     :RADIANCE
     5. Plot type        :SEMI-LOG PLOT (X LINEAR)
     6. Tic marks        :OUTSIDE GRAPH
     7. X-axis length in inches: 5.0
     8. Y-axis length in inches: 5.0

     INPUT ITEM NUMBER TO BE CHANGED OR ZERO TO EXIT
{4}
          <Responding with a "4" causes the program to request a new  >
          <label for the y axis.                                      >

     INPUT THE Y-AXIS LABEL
{Spectral Radiance (W/sr/cm^2/cm^-^1}
          <The label will now be contain units.                       >

     THE FOLLOWING VARIABLES HAVE BEEN SELECTED:
     1. Plot output file :NO.PLT
     2. Plot title       :NO 60 km limb
     3. X-axis label     :wavenumber (cm^-^1)
     4. Y-axis label     :Spectral Radiance (W/sr/cm^2/cm^-^1)
     5. Plot type        :SEMI-LOG PLOT (X LINEAR)
     6. Tic marks        :OUTSIDE GRAPH
     7. X-axis length in inches: 5.0
     8. Y-axis length in inches: 5.0

     INPUT ITEM NUMBER TO BE CHANGED OR ZERO TO EXIT
{5}
          <Responding with a "5" causes the program to list its       >
          <plot type options and request a selection.                 >
```

```
     PLOT TYPES ARE:
     1 - LINEAR PLOT
     2 - SEMI-LOG PLOT (Y LINEAR)
     3 - SEMI-LOG PLOT (X LINEAR)
     4 - LOG-LOG PLOT

     INPUT YOUR CHOICE
{3}
           <Selecting plot type "3" causes the program to keep its    >
           <default semi-log radiance (wavenumber linear) form.        >

     THE FOLLOWING VARIABLES HAVE BEEN SELECTED:
     1. Plot output file :NO.PLT
     2. Plot title       :NO 60 km limb
     3. X-axis label     :wavenumber (cm^-^1)
     4. Y-axis label     :Spectral Radiance (W/sr/cm^2/cm^-^1)
     5. Plot type        :SEMI-LOG PLOT (X LINEAR)
     6. Tic marks        :OUTSIDE GRAPH
     7. X-axis length in inches: 5.0
     8. Y-axis length in inches: 5.0

     INPUT ITEM NUMBER TO BE CHANGED OR ZERO TO EXIT
{6}
           <Responding with a "6" causes the program to list its tic  >
           <mark options and request a selection.                     >

     TIC MARK TYPES ARE:
     1 - INSIDE GRAPH AXES
     2 - OUTSIDE GRAPH AXES

     INPUT YOUR CHOICE FOR TIC MARK DIRECTION
{1}
           <The tic marks will now be on the inside of the plot.      >

THE FOLLOWING VARIABLES HAVE BEEN SELECTED:
     1. Plot output file :NO.PLT
     2. Plot title       :NO 60 km limb
     3. X-axis label     :wavenumber (cm^-^1)
     4. Y-axis label     :Spectral Radiance (W/sr/cm^2/cm^-^1)
     5. Plot type        :SEMI-LOG PLOT (X LINEAR)
     6. Tic marks        :INSIDE GRAPH
     7. X-axis length in inches: 5.0
     8. Y-axis length in inches: 5.0

     INPUT ITEM NUMBER TO BE CHANGED OR ZERO TO EXIT
{7}
           <Responding with a "7" causes the program to request a new >
           <length for the x axis.                                    >

     INPUT THE X-AXIS LENGTH IN INCHES
{4.0}
           <The x axis will be four inches long.                      >
```

```
     THE FOLLOWING VARIABLES HAVE BEEN SELECTED:
     1. Plot output file :NO.PLT
     2. Plot title       :NO 60 km limb
     3. X-axis label     :wavenumber (cm^-^1)
     4. Y-axis label     :Spectral Radiance (W/sr/cm^2/cm^-^1)
     5. Plot type        :SEMI-LOG PLOT (X LINEAR)
     6. Tic marks        :INSIDE GRAPH
     7. X-axis length in inches: 4.0
     8. Y-axis length in inches: 5.0

     INPUT ITEM NUMBER TO BE CHANGED OR ZERO TO EXIT
{7}
           <Responding with a "7" causes the program to request a new  >
           <length for the y axis.                                     >

     INPUT THE Y-AXIS LENGTH IN INCHES
{4.0}
           <The y axis will be four inches long.                       >


THE FOLLOWING VARIABLES HAVE BEEN SELECTED:
     1. Plot output file :NO.PLT
     2. Plot title       :NO 60 km limb
     3. X-axis label     :wavenumber (cm^-^1)
     4. Y-axis label     :Spectral Radiance (W/sr/cm^2/cm^-^1)
     5. Plot type        :SEMI-LOG PLOT (X LINEAR)
     6. Tic marks        :INSIDE GRAPH
     7. X-axis length in inches: 4.0
     8. Y-axis length in inches: 4.0

     INPUT ITEM NUMBER TO BE CHANGED OR ZERO TO EXIT
{0}
           <Free at last.  By responding with a "0" ,the program       >
           <proceeds to the next menu.                                 >

           <The second menu has as defaults the dynamic ranges of      >
           <the x (frequency) and y (radiance) axes.  If only a        >
           <portion of the data is desired for the current plot the    >
           <options 1 and/or 2 should be selected.  The program tries  >
           <to adjust the ranges so that rounded numbers will be       >
           <selected for the tic marks.                                >

     THE FOLLOWING CHARACTERISTICS ARE SET FOR THE CURRENT PLOT:
     1. Minimum frequency          : 1500.0
     1. Maximum frequency          : 4500.049804
     2. Minimum radiance           : 9.999995E-21
     2. Maximum radiance           : 1.000001E-08
     3. Delta x between major ticks: 500.0
     4. Number of minor x ticks    : 4

     INPUT ITEM NUMBER TO BE CHANGED OR ZERO TO EXIT
{1}
```

```
          <Responding with a "1" causes the program to request new     >
          <lower and upper limits of x (frequency).                    >

    INPUT X-MIN OR MINIMUM FREQUENCY FOR PLOT
{1600}

    INPUT X-MAX OR MAXIMUM FREQUENCY FOR PLOT
{2200}

    THE FOLLOWING CHARACTERISTICS ARE SET FOR THE CURRENT PLOT:
    1. Minimum frequency            : 1600.0
    1. Maximum frequency            : 2200.020019
    2. Minimum radiance             : 9.999995E-21
    2. Maximum radiance             : 1.000001E-08
    3. Delta x between major ticks: 500.0
    4. Number of minor x ticks      : 4

    INPUT ITEM NUMBER TO BE CHANGED OR ZERO TO EXIT
{2}
          <Responding with a "2" causes the program to request new     >
          <lower and upper limits of y (radiance).                     >

    INPUT Y-MIN OR MINIMUM RADIANCE FOR PLOT
{1e-14}

    INPUT Y-MAX OR MAXIMUM RADIANCE FOR PLOT
{1e-8}

    THE FOLLOWING CHARACTERISTICS ARE SET FOR THE CURRENT PLOT:
    1. Minimum frequency            : 1600.0
    1. Maximum frequency            : 2200.020019
    2. Minimum radiance             : 9.999993E-15
    2. Maximum radiance             : 1.000001E-08
    3. Delta x between major ticks: 500.0
    4. Number of minor x ticks      : 4

    INPUT ITEM NUMBER TO BE CHANGED OR ZERO TO EXIT
{3}
          <Responding with a "3" causes the program to request a       >
          <new delta x (frequency interval) between major tics.        >

    INPUT DELTA X BETWEEN MAJOR TICKS
{200}
          <There will be 200 cm^-^1 between major tics.                >

    THE FOLLOWING CHARACTERISTICS ARE SET FOR THE CURRENT PLOT:
    1. Minimum frequency            : 1600.0
    1. Maximum frequency            : 2200.020019
    2. Minimum radiance             : 9.999993E-15
    2. Maximum radiance             : 1.000001E-08
    3. Delta x between major ticks: 200.0
    4. Number of minor x ticks      : 4
```

```
     INPUT ITEM NUMBER TO BE CHANGED OR ZERO TO EXIT
{4}
            <Responding with a "4" causes the program to request a      >
            <new number of minor x ticks.                                >

     INPUT NUMBER OF MINOR X TICKS
{3}
            <The number of minor tics has been changed to "3"            >

     THE FOLLOWING CHARACTERISTICS ARE SET FOR THE CURRENT PLOT:
     1. Minimum frequency           : 1600.0
     1. Maximum frequency           : 2200.020019
     2. Minimum radiance            : 9.999993E-15
     2. Maximum radiance            : 1.000001E-08
     3. Delta x between major ticks: 200.0
     4. Number of minor x ticks     : 3

     Input item number to be changed or zero to exit
{0}
            <Free at last. By responding with a "0" the data will be    >
            <plotted according to the current options.                   >
```

The result of the interactive session is that a file named NOSPEC.OUT is read from disk and a plot file named NO.PLT is generated with the labels and specifics generated during the terminal session. The resulting plot is presented in Figure 5.

The plot package allows superscripts, subscripts and Greek symbols to be used in the plot and axis labels. This is accomplished using key characters. Quotes, ", which surround the key characters in this text should not be typed at a terminal session.

¦@ The symbol following a "^" will be plotted as a superscript.

¦@ The symbol following a "\" will be plotted as a subscript.

¦@ The symbol following a "¦" will be replaced by a greek symbol according to Table 16.

¦@ The symbol following a "#" will overwrite the previous symbol, that is a backspace will be performed prior to writing the symbol.

The above key characters can be plotted by preceding them with a "¦". (i.e., "¦¦" will result in a "¦" being plotted, etc.)

TABLE 16. THE KEYS FOR GREEK LETTERS AND SPECIAL CHARACTERS.

KEY	GREEK LETTER	ASCII VALUE
0	CAPITAL GAMMA	48
1	CAPITAL DELTA	49
2	CAPITAL THETA	50
3	CAPITAL LAMBDA	51
4	CAPITAL PI	52
5	CAPITAL SIGMA	53
6	CAPITAL PHI	54
7	CAPITAL PSI	55
8	CAPITAL OMEGA	56
9	INFINITY	57
>	GREATER THAN OR EQUAL TO	62
A	LOWER CASE ALPHA	65
B	LOWER CASE BETA	66
C	LOWER CASE GAMMA	67
D	LOWER CASE DELTA	68
E	LOWER CASE EPSILON	69
F	LOWER CASE ZETA	70
G	LOWER CASE ETA	71
H	LOWER CASE THETA	72
I	DEL OPERATOR	73
K	SCRIPT l	75
L	LOWER CASE LAMBDA	76
M	LOWER CASE MU	77
N	LOWER CASE NU	78
O	LOWER CASE XI	79
P	LOWER CASE PI	80
R	LOWER CASE RHO	82
S	LOWER CASE SIGMA	83
T	LOWER CASE TAU	84
U	LOWER CASE PHI	85
V	LOWER CASE PSI	86
W	LOWER CASE OMEGA	87
X	LOWER CASE CHI	88
Y	VECTOR HAT	89
[	RIGHT ARROW	91
]	LEFT ARROW	93

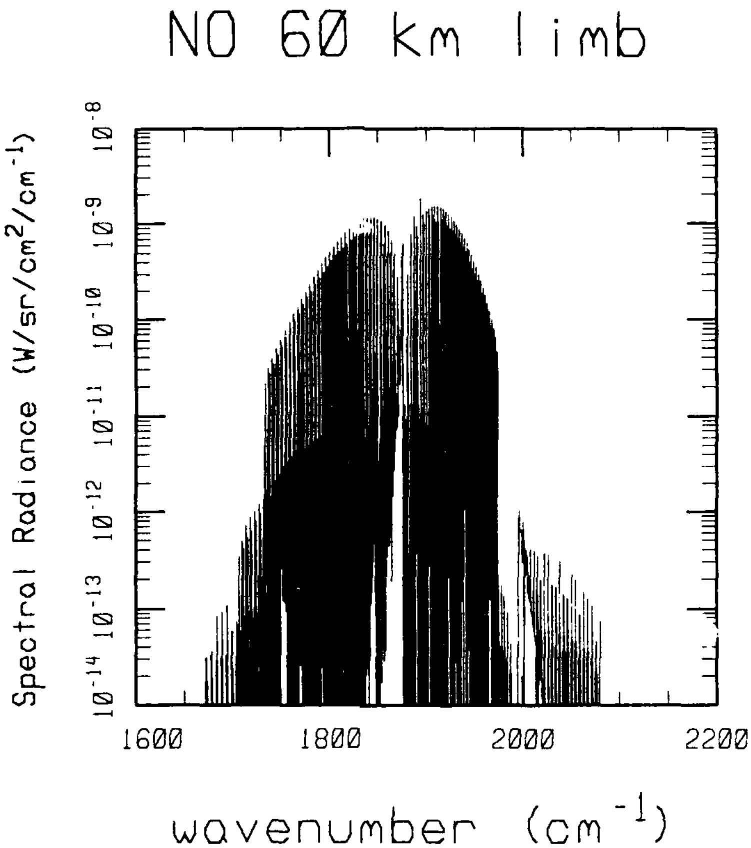

Figure 5. Sample NO Spectral Radiance Plot Created During Interactive Session.

7. REFERENCES

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APPENDIX A

IMPLEMENTATION INSTRUCTIONS

The magnetic tape is unlabeled, ASCII-coded, 1600 BPI and contains the FORTRAN source code, input data sets and three test cases for the Strategic High-Altitude Radiance Code, SHARC. This model calculates the spectral radiance from 250 to 5000 cm^{-1} for arbitrary geometries from 60 to 300 km. SHARC includes radiance from CO_2, H_2O, NO, O3, and CO.

The tape contains 50 files. There are a total of ten FORTRAN files: seven for SHARC, one for the interpreter, one for the plotting package and one for the ASCII to binary conversion program. The others consist of nine model atmosphere files, one generic input file, 15 input files for the five current molecular radiators, one ASCII line position and strength file, five interpreter output files, and input and output files from three test cases. The input and output for the test cases are included in Appendices E and F of this manual. The test cases run on a Hewlett-Packard 9040, Series 500, minicomputer which has a 32-bit word size.

The tape format is:

9 track
1600 BPI
unlabeled ASCII
50 files
80 characters per record (files 1-35)
132 characters per record (files 36-50)
20 records per block.

The files are:

1	sharc	Main program	FORTRAN	588 lines
2	chemkin	CHEMKIN subroutines	FORTRAN	1068 lines
3	geomtry	Geomtry subroutines	FORTRAN	874 lines
4	input	Input subroutines	FORTRAN	3840 lines
5	nemesis	NEMESIS subroutines	FORTRAN	1209 lines
6	output	Output subroutines	FORTRAN	1092 lines
7	spctra	Spectral Radiance subroutines	FORTRAN	1042 lines
8	interp	CHEMKIN Interpreter program	FORTRAN	2151 lines

9	pltpak	Plotting Package	FORTRAN	3609 lines
10	binary	Program to convert Line data base to binary	FORTRAN	33 lines
11	SAT1976.DAT	1976 Standard	DATA	319 lines
12	SAT15AN.DAT	15^{o} Annual	DATA	951 lines
13	SAT30SM.DAT	30^{o} Summer	DATA	951 lines
14	SAT30WN.DAT	30^{o} Winter	DATA	951 lines
15	SAT45SP.DAT	45^{o} Spring/Fall	DATA	951 lines
16	SAT45SM.DAT	45^{o} Summer	DATA	951 lines
17	SAT45WN.DAT	45^{o} Winter	DATA	951 lines
18	SAT60SM.DAT	60^{o} Summer	DATA	951 lines
19	SAT60WN.DAT	60^{o} Winter	DATA	951 lines
20	SHARC.INP	Default Input File	DATA	116 lines
21	CO2BAND.DAT	CO_2 Band Information file	DATA	349 lines
22	CO2KIN.DAT	CO_2 Kinetics file	DATA	252 lines
23	CO2STAT.DAT	CO_2 Transitions and State file	DATA	54 lines
24	COBAND.DAT	CO Band Information file	DATA	34 lines
25	COKIN.DAT	CO Kinetics file	DATA	36 lines
26	COSTAT.DAT	CO Transitions and State file	DATA	11 lines
27	H2OBAND.DAT	H_2O Band Information file	DATA	164 lines
28	H2OKIN.DAT	H_2O Kinetics file	DATA	82 lines
29	H2OSTAT.DAT	H_2O Transitions and State file	DATA	27 lines
30	NOBAND.DAT	NO Band Information file	DATA	37 lines
31	NOKIN.DAT	NO Kinetics file	DATA	32 lines
32	NOSTAT.DAT	NO Transitions and State file	DATA	11 lines
33	O3BAND.DAT	O_3 Band Information file	DATA	263 lines
34	O3KIN.DAT	O_3 Kinetics file	DATA	199 lines
35	O3STAT.DAT	O_3 Transitions and State file	DATA	46 lines
36	LINE.ASC	ASCII Version of Line Parameter File	DATA	95659 lines
37	CO2OUT.DAT	CO_2 Interpreter output	DATA	360 lines
38	COOUT.DAT	CO Interpreter output	DATA	72 lines
39	H2OOUT.DAT	H_2O Interpreter output	DATA	133 lines
40	NOOUT.DAT	NO Interpreter output	DATA	64 lines
41	O3OUT.DAT	O_3 Interpreter output	DATA	326 lines

FIRST TEST CASE			
42 SHARC1.INP	Test default file	DATA	116 lines
43 SHARC1.OUT	General output	DATA	1366 lines
44 SHARC1.SPC	Spectral file	DATA	4543 lines
SECOND TEST CASE			
45 SHARC2.INP	Test default file	DATA	116 lines
46 SHARC2.OUT	General output	DATA	1258 lines
47 SHARC2.SPC	Spectral file	DATA	445 lines
THIRD TEST CASE			
48 SHARC3.INP	Test default file	DATA	116 lines
49 SHARC3.OUT	General output	DATA	113 lines
50 SHARC3.SPC	Spectral file	DATA	445 lines

The FORTRAN source code for SHARC is found in the first seven files on the tape. These files should be compiled and linked to make the executable version of SHARC. The only system-dependent routine is subroutine DATE which is in the input file. This routine should return the date in a CHARACTER*32 variable called ADATE. All of the file open statements are in the main SHARC routine, and may need to be changed for your machine. The SHARC subroutines are listed in Appendix C, and execution of SHARC is described in Section 4.

The INTERPRETER should be compiled as a stand-alone program. INTERPRETER subroutines are described in Appendix B and use of the program is discussed in Section 4.

The plotting package should be compiled as a stand-alone program. System-dependent routines which are required in the plotting package are discussed in Appendix D.

The routine called binary converts the ASCII line parameter file shipped on the tape to a binary form for SHARC. Binary should be compiled as a stand-alone program. When binary is executed it reads a file called LINE.ASC and outputs a binary version of the file. The new file is called SHARC.LIN. The conversion of LINE.ASC to SHARC.LIN is performed only once.

APPENDIX B

INTERPRETER SUBROUTINES

The INTERPRETER reads this symbolic description of an arbitrary chemical kinetics mechanism and translates it into the appropriate differential equations. The output from the INTERPRETER used by SHARC is a binary "linking" file which contains all the information describing the kinetic mechanism for a given molecular radiator.

A list of the subroutines comprising the INTERPRETER with a brief description follows.

MAIN MAIN opens the input and output files used by the INTERPRETER, and defines the following parameters used to set the maximum size of storage arrays:

KMX (=100)	The maximum number of species allowed during the execution of the INTERPRETER.
LENSYM(=10)	The maximum length of a species symbol.
MXLEN (=80)	The maximum length of a reaction input string.
MAXSP (=8)	The maximum number of species allowed in any given reaction.
MAXTB (=6)	The maximum number of third bodies allowed in any given reaction.

CKINTP CKINTP is the driver routine which reads the species and reaction mechanism input, checks for proper syntax, and writes the "linking" file.

BLKDAT Block data defines the Hollerith characters for the species, as well as a number of Hollerith constants used in the code.

CKTBD This subroutine checks to make sure that different third-body efficiency factors have not been input for any species.

CKINTC This routine converts a character input string into internal code.

CKNUM CKNUM converts a character string into a specified number of real numbers. The character string may contain integer, floating point, or exponential numbers separated by at least one blank.

<u>CKSCAN</u> This subroutine scans a character string (in internal code) and converts all digits into integer numbers and all species into species indicies.

<u>CKPARS</u> CKPARS checks the input string for format errors (i.e., enforce the rules given in Section 3.1)

<u>CKERR</u> This subroutine writes the error messages into the output file.

APPENDIX C

SHARC SUBROUTINES

A list of the subroutines comprising the various SHARC modules described in Section 2.2 is given below.

MAIN — The SHARC MAIN routine opens the input and output files used by SHARC, and calls: the input and output routines, the CHEMKIN/NEMESIS driver, the GEOMETRY module, and the SPCRAD module. MAIN also defines the following parameters used to determine the size of various arrays.

NBINMX(=10000)	Maximum number of radiance bins.
NBMAX (=30)	Maximum number of bands.
NBYMAX(=61)	The maximum number of layer boundaries.
NCHMAX(=80)	Maximum length of reaction input string.
NDFLTS(=20)	The number of lines of input in SHARC.INP.
NIMAX(=200)	The maximum number of reactions.
NKMAX (=50)	The maximum number of species allowed.
NLNMAX(=10)	The maximum length of a species symbol.
NLYMAX(=60)	The maximum number of layers in model atmosphere.
NRDMX (=5)	Maximum number of molecular emitters.
NSMAX (=20)	The maximum number of bins for band distributions.
NSPMAX (=8)	The maximum number of species allowed in any given reaction.
NTBMAX (=6)	The maximum number of third bodies allowed in any given reaction.

INPUT Module

ATMDEN — This subroutine loads atmospheric profile into the appropriate local arrays and calculates the thickness of the atmospheric layers.

ATMIN — ATMIN identifies the atmospheric species in the general species list, and reads atmospheric profile (containing the species number densities and kinetic temperature).

ATMSYM — ATMSYM sets up the Hollerith arrays identifying the atmospheric species and an indexing array which relates the atmospheric species to the species read by CKLINK.

BANDIN — BANDIN reads the molecular bands file (Section 3.3), which describes the line strength distribution function parameters for each vibrational transition.

BLKDAT — BLOCK DATA contains some fundamental constants, species molecular weights, the average atmospheric temperature for NEMESIS, and the optical depth cutoff parameter for the relayering option.

DATE — DATE calls a system-dependent routine to determine the date and time of the SHARC run.

ACTIVE — This function reads the first parameter in the SHARC.INP input file. If active is 1 SHARC runs interactively, if active is 0 SHARC runs in the batch/background mode.

FILCHK — This routine opens all molecular input files to insure that the files really exist before any computational time has been used.

INATM — This is the interactive input routine for reviewing/changing the user's choice of model atmosphere.

INGEO — This is the interactive LOS geometry routine. The user can review and change the selected LOS geometry.

INMOL — This is the interactive input routine for reviewing/changing the desired molecular radiators. Currently the code supports H_2O, CO_2, O_3, CO, and NO.

INNAME — This is the interactive input routine for reviewing/changing the title of the calculation.

LENS — This function counts the number of characters in the title.

INNEM — This is the input routine for reviewing/changing the NEMESIS parameters.

INOUT — This routine allows the user to review and/or modify the amount of output place in the general output file.

INPOP — This routine allows the user to review and/or modify the name and status of the population file.

INSOL — This routine is used to change/review the solar zenith angle.

INSPEC This is the interactive input routine used to change and/or modify the spectral range and resolution. The relayering option is also selected in this menu.

LOADDE This routine opens and loads the input data found in SHARC.INP into the array DFLTS. IF SHARC.INP is not found this routine loads in a default set of parameters.

POLL This routine contains the main interactive input module menu and reads the user's choice.

RADIN This subroutine reads the molecular states file (Section 3.2), which contains the molecular radiator, the vibrational states included in the mechanism and the transitions to be considered by NEMESIS and SPCRAD.

READRD READRD reads the list of molecular radiators and the names of the associated linking, states, and bands files.

RETREV This routine reads the saved population file data.

XNUM XNUM translates an alphanumeric character string containing N integer, real, or exponential numbers into their respective real values.

CHEMKIN Module

CKLINK CKLINK reads the "linking" file created by INTERP, and defines the arrays containing information on species names, chemical kinetics mechanism (i.e., the stoichiometric coefficients) and the rate constants.

LUDCMP/LUBKSB
These two subroutines use a LU decomposition procedure to solve a set of simultaneous linearly independent algebraic equations (the steady-state equations). The major limitation to the steady-state procedure used here is the assumption that the rate equations are linear in the unknown vibrational population, i.e., there is no energy exchange among the emitting species. This restriction can be easily relaxed by using an algorithm which solves nonlinear equations (as opposed to LUDCMP/LUBKSB).

POPLTE This subroutine computes the LTE populations for N_2 and O_2 which are subsequently used in the calculation of vibrationally excited states for CO and H_2O.

POPN2 This subroutine computes the effective excited state populations for N_2 using the Kumer and James approach.

RATCON This subroutine uses the kinetic data from the linking file to compute the rate constants as a function of temperature. The assumed from of the rate constant is

$$k = A\, T^{\beta} \exp(-E/T - C/T^{1/3}) \quad ,$$

where A is the pre-exponential factor, β is the exponent of the temperature term, E is the activation energy (can also be used to write a reverse rate constant in terms of the forward rate constant via detailed balance), and C is the (historic) SSH $T^{1/3}$ coefficient.

RATSCL This subroutine computes the effective rate constant for the $CO_2(00011) + N_2(0)$ quenching process following Kumer and James.

STEADY The information obtained from CKLINK is used by STEADY to set up the steady state equations

$$\sum_{i=1}^{I} (\nu'_{ki} - \nu_{ki}) k_i \prod_{k=1}^{K} [C_k]^{\nu_{ki}} = 0 \quad .$$

STEADY then calls LUDCMP and LUBKSB to solve the set of linear algebraic equations for the number densities c_k.

NEMESIS Module

ARATE ARATE solves the two-state steady-state equation for the atmospheric excitation rate constant.

COLDEN COLDEN computes the total column density for each atmospheric layer for the radiating species.

DOPLER This subroutine determines the emission frequency using a Doppler lineshape function. The absorption cross section at this frequency is also computed.

DWIDTH DWIDTH calculates the Doppler halfwidth for the transition.

E2 E2 computes the second exponential integral as a function of optical depth.

EMISS This subroutine locates the Einstein A coefficient for the current transition, and also calculates the sum of all Einstein A coefficients for all transitions from the upper vibrational state.

ERATE ERATE calculates the earthshine excitation rate for each atmospheric layer.

ESCPRB ESCPRB normalizes the escape probabilities calculated by subroutine PATH for each layer.

ESHINE ESHINE calculates the earthshine flux for the current transition using the specified effective earthshine temperature.

EWIDTH EWIDTH calculates the equivalent width for a Doppler line.

GASDEV GASDEV generates random numbers from a Gaussian distribution centered around 0.

MULSCT MULSCT calculates the nth-order multiple scattering enhancement to the excited-state number density using the single-scattering enhancement matrix.

NEMDRV This subroutine calls the appropriate CHEMKIN/NEMESIS subroutines to compute the vibrationally excited state populations.

NEMRXN NEMRXN identifies the excitation and relaxation processes in the chemical kinetics mechanism for the current transition being considered by NEMESIS.

NEMSIS NEMSIS is the driver routine to compute the escape probabilities and enhanced excited-state number densities for each atmospheric layer using Monte Carlo integration of atmospheric layers, line strengths, and frequencies.

PATH PATH integrates through the atmospheric layers to determine the escape probabilities and single-scattering enhancements.

PICKSJ PICKSJ determines the line strength selected from the line strength distribution function.

PICKZ PICKZ finds the initial location and the corresponding layer for photon emission.

QUENCH This subroutine computes the total quenching rate for the upper state of the transition.

RANF This machine-dependent function generates uniformly distributed random numbers between 0 and 1.

SOLAR This subroutine calculates the solar flux at the transition frequency assuming a 5500 K blackbody.

SRATE SRATE calculates the solar excitation rate for each atmospheric layer.

GEOMETRY Module

AMOUNT This subroutine calculates column densities COLUMN(i,j) for the i^{th} segment, SEG(i), and j^{th} species. These are obtained by multiplying the segment length by average species concentrations.

GEOMET This subroutine accepts as input a minimal set of LOS parameters. The minimal set depends on desired path type as flagged by IPATH and ICASE. The output of GEOMET is a complete set of LOS parameters.

IPATH2 This subroutine is called from GEOMET if IPATH = 2. The input to this subroutine is a minimal set of LOS parameters; the output is a complete set of such parameters.

IPATH3 This subroutine is called from GEOMET if IPATH = 3. The input to this subroutine is a minimal set of LOS parameters; the output is a complete set of such parameters.

IPATH4 This subroutine is called from GEOMET if IPATH = 4. The input to this subroutine is a minimal set of LOS parameters; the output is a complete set of such parameters.

LOS This subroutine calculates the parametric equation of the straight line that is the LOS. Thus the quantities that are calculated are the unit direction vector of LOS in the direction which points from the observer position to the source position, and a position on the straight line which is taken to be that of the observer.

PASECT This subroutine, using the equation of the LOS and its length (RANGE), calculates which layer boundaries are intersected by the LOS, and the distances of these intersections from the observer.

SL Solves for the points of intersection between a line and a sphere. SL is used by PASECT. It uses the subroutine QUAD which is a quadratic equation solver.

QUAD This is a quadratic equation solver used by subroutine SL.

SORT This subroutine sorts the outputs of PASECT which are the arrays of layer boundaries intersected, and of the distances of the intersections from observer to source.

SGMNT SGMNT outputs the array SEG which contain the "intralayer" distances of the LOS in order of traversal from observer to source. It also computes an integer array MINLR which contains the lower layer boundary of each segment.

PRSCAL This subroutine is used to calculate the total pressure of the atmospheric layers containing the LOS. It uses the atmosphere data file to obtain gas concentrations and temperatures, and calculates pressure via the ideal gas law.

ASNCHK The input to this subroutine is the argument to any ASIN or ACOS call. Its purpose is to force the argument to lie within the range of -1 to 1, and print a warning message if it is not. If the input to ASNCHK is within range then ASNCHK does nothing.

CHECK This subroutine performs a cursory check on the LOS inputs to GEOMET. GEOMET calls CHECK prior to calling the IPATHn routines. CHECK terminates further SHARC execution when it encounters faulty inputs.

RCHECK This is an auxiliary routine used by CHECK to perform range checking on an argument.

SPCRAD Module

BNDLOC This subroutine compares the transition listed on the HITRAN tape and the transitions the user has selected to include in the calculation.

COLDNL This routine calculates the column densities of excited-state species along the LOS.

CRTGDS This routine calculates column density weighted line widths.

LINRD This routine reads the binary line parameter file, one line at a time.

PRTROT This routine calculates the rotational partition function.

RELAYR This routine relayers a n layer atmosphere into $\sqrt{n}$ layers. The use of a relayered atmosphere is limited to optically thin lines and is a user-selected option.

SPCRAD This is the spectral radiance routine and is called by the main SHARC routine. This routine calls LINRD to read an individual line, calls BNDLOC to determine if this line is for a user-selected transition, calls STRGTH to scale the line strength to the proper rotational and vibrational temperatures and calls WVOIGT to calculate the equivalent width for the line. The end result of this routine is the spectral radiance for a line which is stored in array RADBIN.

STRGTH STRGTH scales the line strength to the current vibrational and rotational temperatures. The reference temperature of 296K has already been removed from the SHARC line parameter database.

VIBES When ICHOIC=1 this routine converts 1982 vibrational assignments to 1985 format. When ICHOIC=2 the routine converts 1985 format to 1982 vibrational assignments. This routine is from the HITRAN line selection program.

WVOIGT This routine calculates an equivalent width for an isolated Doppler-Lorentzian (Voigt) line. This routine uses an approximation from the NASA IR Handbook that is good to 10% for all optical depths.

OUTPUT Module

AFGLNK AFGLNK associates the AFGL number with each atmospheric species.

ATMOUT ATMOUT prints the atmospheric profile.

BANNER BANNER outputs the SHARC banner identifying the run.

BNDOUT This subroutine prints the line strength distribution function parameters.

BRDOUT BRDOUT summarizes the calculated band radiances for each transition. The number of lines used in the radiance calculation is also printed.

DUMPDE This routine writes a new SHARC.INP file, after it has been updated through the interactive menus.

EMTOUT This subroutine outputs the user-selected list of molecular radiators.

EXCOUT EXCOUT outputs the number densities as a function of altitude for each vibrational state in the mechanism.

GEMOUT GEMOUT writes out a breif summary of the LOS information to SHARC.OUT.

NEMOUT This subroutine prints out some of the inputs used by NEMESIS.

POPTMP POPTMP returns a vibrational temperature when passed the populations of two levels and the energy gap between them.

RADOUT RADOUT outputs the information contained in the molecular states file.

RETOUT RETOUT writes a summary of the population file to SHARC.OUT when an old population file is used in a new calculation.

SAVE SAVE writes the population file.

SPCOUT SPCOUT writes the spectral radiance as a function of wavenumber to SHARC.SPC.

VBTOUT VBTOUT outputs the vibrational temperatures as a function of altitude for each vibrational state in the mechanism.

VIBTMP This routine calculates vibrational temperatures of excited-state species.

APPENDIX D

PLOTTING PACKAGE

The plotting software is a separate package which can be used to plot the spectral output of a SHARC computation. The program is written in Fortran 77. The program is designed to be as device independent as possible. It requires only standard Calcomp calls to initialize and terminated plotting, and a standard Calcomp call to move the pen. External routines which must be supplied by the user include INITPZ, ENDPLT and PPLT which are described below. All other aspects of plotting are device independent.

INITPZ — This subroutine initializes all system specific requirements for plotting and opens the plot file. Subroutine arguments are:

- PLTFIL - a character string which is the name of the plot file to be sent to the printer/plotter,
- NCPPLT - an integer equal to the number of characters in the plot file name,
- NPLT - the file unit number for the plot file.
- NERR - the file unit number for writing any error messages.

ENDPLT — ENDPLT terminates plotting and closes the plot files.

PPLT — PPLT draws a line or moves the pen to a new set of (X,Y) coordinates relative to the current origin. Subroutine arguments are:

- X - a real number giving the x position of the pen,
- Y - a real number giving the y position of the pen,
- IPEN - a pen control parameter. IPEN has the following meaning:

2	Lower pen and move
3	Raise pen and move
-2	Lower pen, move and reset origin to x,y
-3	Raise pen, move and reset origin to x,y

APPENDIX E

TEST CASE -- INPUTS

This appendix includes the SHARC input files for three test cases. The output generated from these input files is contained in Appendix F. The first file is for a batch/background calculation. The second and third files are for interactive execution.

SHARC.INP for test 1, called SHARC1.INP in Appendix A.

```
C0 FILE SHARC.INP
C0 THIS FILE HOLDS THE DEFAULT VALUES FOR SHARC
C0 THIS FILE IS UPDATED TO THE CURRENT VALUES OF THE PARAMETERS
C0 EACH TIME SHARC IS RUN.
C0
C1 THE FIRST LINE CONTAINS THE INTERACTIVE/BATCH OPTION
C1 IF IT EQUALS 1, SHARC WILL RUN INTERACTIVELY, ALLOWING
C1 THE USER TO UPDATE OPTIONS.  IF IT EQUALS 0, SHARC WILL
C1 RUN IN BATCH MODE. THIS WILL NOT ALLOW THE USER TO UPDATE SHARC.INP.
C1 THIS FILE MUST BE EDITTED TO CHANGE THE VALUE OF THIS PARAMETER.
C1 FORMAT = I4
C1##
   0
C2 TITLE FOR CALCULATION   WILL APPEAR ON TOP OF GENERAL OUTPUT FILE
C2 FORMAT(1X,A68,I3)
C#################################################################### ###
 CO, CO2, NO, H2O, O3  DAYTIME  1976 STANDARD ATMOSPHERE                55
C3 LINE 2 CONTAINS THE VARIABLE IATMOS.
C3 THIS VARIABLE IS USED TO SELECT THE DESIRED MODEL ATMOSPHERE AND
C3 THE ATMOSPHERIC FILE NAME.
C3 FORMAT = I4,2X,A11
C3##  ###########
   1  SAT1976.DAT
C4 LINE 3 CONTAINS THE EXO-ATMOSPHERIC TEMPERATURE AND
C4 A CONTROL PARAMETER WHICH SELECTS EITHER THE DAY(4) OR NIGHT(3)
C4 OPTION FOR THE MODEL ATMOSPHERE.
C4 FORMAT = E12.5,2X,A5
C4 #####E+##  #####
  .10000E+04  DAY
C5 NEMESIS CONTROL PARAMETERS
C5 WARNING: CHANGING THESE PARAMETERS WILL EFFECT THE ACCURACY
C5 OF THE MONTE CARLO SIMULATION.
C5 TOTAL NUMBER OF PHOTONS, MAXIMUM ORDER OF SCATTERING
C5 GLOBAL SUNSHINE AND EARTHSHINE PARAMETERS (1=YES , 0=NO)
```

```
C5 FORMAT=2X,6I,2X,6I,2x,I6,2X,I6
C5 ###### ###### ###### ######
   10000     200      1      1
C6 AFGL# FOR MOLECULE,LINKING FILE, STATE FILE, BAND FILE
C6 UP TO 5 RADIATORS H2O=1, CO2=2, O3=3, CO=5, NO=8
C6FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C6#### ############ ############ ############
     1  H2OLINK.DAT  H2OSTAT.DAT  H2OBAND.DAT
C7 FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C7#### ############ ############ ############
     2  CO2LINK.DAT  CO2STAT.DAT  CO2BAND.DAT
C8 FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C8 ### ############ ############ ############
     3  O3LINK.DAT   O3STAT.DAT   O3BAND.DAT
C9 FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C9 ### ############ ############ ############
     5  COLINK.DAT   COSTAT.DAT   COBAND.DAT
C10FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C10### ############ ############ ############
     8  NOLINK.DAT   NOSTAT.DAT   NOBAND.DAT
C11 SOLAR ZENITH ANGLE IN DEGREES. 0 FOR THE SUN OVERHEAD
C11( 0.0 WHEN THE SUN IS OVERHEAD)
C11FORMAT = E12.5
C#.#####E+##
  .20000E+02
C12NEXT 6 LINES CONTAIN LOS GEOMETRY INFORMATION
C12LINE 12 CONTAINS IPATH AND ICASE
C12FORMAT = I4,2X,I4
C12#  ####
   2     5
C13LINE 13 CONTAINS H1ALT, H1LONG AND H1LAT
C13FORMAT = 3(E12.7,2X)
C13#####E+##  .#######E+##  .#######E+##
.7000000E+02  .6200000E+02  .5000000E+02
C14LINE 14 CONTAINS H2ALT, H2LONG AND H2LAT
C14FORMAT = 3(E12.7,2X)
C14#####E+##  .#######E+##  .#######E+##
.2900000E+03  .6200000E+02  .6000000E+02
C15LINE 15 CONTAINS RANGE,BETA,A0
C15FORMAT = 3(E13.8,1x)
C15######E+## .########E+## .########E+##
 .6000000E+02  .1200000E+03  .0000000E+00
C16LINE 16 CONTAINS B0,HMIN,LEN
C16FORMAT = 2(E13.8,1x),I4
C16######E+## .########E+## ####
 .9000000E+02  .6000000E+02    0
C17Line 17 CONTAINS TIME,IDAY,ICASES
C17TIME IS GMT TIME (0. TO 24.)
C17IDAY IS FROM 1 TO 366
C17THESE OPTIONS ARE NOT USED IN SHARC-1
C17FORMAT = E12.7,2X,2I4
C17#####E+##  #### ###
```

```
 .0000000E+00      6   1
C18SPECTRAL INFORMATION IN CM-1
C18 WMIN,WMAX,BINRES(RESOLUTION),IRELAY=1 FOR RELAYERING
C18FORMAT = 2X,3(E12.5,2X),I2,2X,E12.5
C18#.#####E+##  ##.#####E+##  ##.#####E+##  ##
    .25000E+03    .50000E+04    .10000E+01   0
C19 OUTPUT CONTROL PARAMETERS:
C19 1) MODEL ATMOSPHERE OUTPUT ==>1 FOR FULL LISTING
C19 2) ATMOSPHERIC MOLECULE IDENTIFICATION == >2 FOR TABLE
C19 3) MOLECULAR RADIATORS INFORMATION ==>2 FOR ECHO OF INPUTS
C19 4) NOT CURRENTLY USED
C19 5) SELECTED TRANSITIONS ==>1 FOR TRANSITIONS SELECTED
C19 6) MOLECULAR BAND INFORMATION ==>2 FOR ECHO OF BAND INFORMATION
C19 7) NEMESIS OUTPUT ==>1 NEMESIS ONLY ==2 FOR POST POPULATIONS
C19 8) FINAL STATE POPULATIONS ==>1 YES
C19 9) FINAL VIBRATIONAL TEMPERATURES ==>1 YES
C19 10)LOS OUTPUT ==>1 FOR COLUMN DENSITIES
C19 11)CURRENTLY NOT USED
C19 12)SPECTRAL RADIANCE OUTPUT ==>1 FOR RADIANCE OUTPUT IN GENERAL
C19    OUTPUT FILE  SPECTRAL INFORMATION IS ALWAYS PLACED IN SPEC.OUT
C19 FORMAT = 12(2X,I2)
C  1   2   3   4   5   6   7   8   9  10  11  12
C ##  ##  ##  ##  ##  ##  ##  ##  ##  ##  ##  ##
   1   0   0   0   1   0   0   1   1   1   0   0
C20 SAVED POPULATIONS FILE NAME AND ISAVE
C20 WHEN ISAVE = 0 POPULATIONS ARE SAVED
C20 ISAVE = 1 SAVED POPULATIONS ARE USED FOR CALCULATION
C20 FORMAT=(2X,A20,2X,I4)
C2####################  ####
  D1976.DAT                1
```

SHARC.INP for test 2, called SHARC2.INP in Appendix A.

```
CO FILE SHARC.INP
CO THIS FILE HOLDS THE DEFAULT VALUES FOR SHARC
CO THIS FILE IS UPDATED TO THE CURRENT VALUES OF THE PARAMETERS
CO EACH TIME SHARC IS RUN.
CO
C1 THE FIRST LINE CONTAINS THE INTERACTIVE/BATCH OPTION
C1 IF IT EQUALS 1, SHARC WILL RUN INTERACTIVELY, ALLOWING
C1 THE USER TO UPDATE OPTIONS.  IF IT EQUALS 0, SHARC WILL
C1 RUN IN BATCH MODE. THIS WILL NOT ALLOW THE USER TO UPDATE SHARC.INP.
C1 THIS FILE MUST BE EDITTED TO CHANGE THE VALUE OF THIS PARAMETER.
C1 FORMAT = I4
C1##
   1
C2 TITLE FOR CALCULATION   WILL APPEAR ON TOP OF GENERAL OUTPUT FILE
C2 FORMAT(1X,A68,I3)
C#################################################################### ###
 CO    NIGHT  WINTER  45-LATITUDE                                       31
C3 LINE 2 CONTAINS THE VARIABLE IATMOS.
C3 THIS VARIABLE IS USED TO SELECT THE DESIRED MODEL ATMOSPHERE AND
C3 THE ATMOSPHERIC FILE NAME.
C3 FORMAT = I4,2X,A11
C3##  ###########
   7  SAT45WN.DAT
C4 LINE 3 CONTAINS THE EXO-ATMOSPHERIC TEMPERATURE AND
C4 A CONTROL PARAMETER WHICH SELECTS EITHER THE DAY(4) OR NIGHT(3)
C4 OPTION FOR THE MODEL ATMOSPHERE.
C4 FORMAT = E12.5,2X,A5
C4 #####E+##  #####
  .15000E+04  NIGHT
C5 NEMESIS CONTROL PARAMETERS
C5 WARNING: CHANGING THESE PARAMETERS WILL EFFECT THE ACCURACY
C5 OF THE MONTE CARLO SIMULATION.
C5 TOTAL NUMBER OF PHOTONS, MAXIMUM ORDER OF SCATTERING
C5 GLOBAL SUNSHINE AND EARTHSHINE PARAMETERS (1=YES , 0=NO)
C5 FORMAT=2X,6I,2X,6I,2x,I6,2X,I6
C5 #####  ######  ######  ######
   10000     200       0       1
C6 AFGL# FOR MOLECULE,LINKING FILE, STATE FILE, BAND FILE
C6 UP TO 5 RADIATORS H2O=1, CO2=2, O3=3, CO=5, NO=8
C6FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C6####  ###########  ###########  ###########
     5  COLINK.DAT   COSTAT.DAT   COBAND.DAT
C7 FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C7####  ###########  ###########  ###########
     0  NOLINK.DAT   NOSTAT.DAT   NOBAND.DAT
C8 FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C8 ###  ###########  ###########  ###########
     0  NOLINK.DAT   NOSTAT.DAT   NOBAND.DAT
C9 FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
```

```
C9 ###  ###########  ###########  ###########
     0  NOLINK.DAT   NOSTAT.DAT   NOBAND.DAT
C10FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C10###  ###########  ###########  ###########
     0  NOLINK.DAT   NOSTAT.DAT   NOBAND.DAT
C11 SOLAR ZENITH ANGLE IN DEGREES. 0 FOR THE SUN OVERHEAD
C11( 0.0 WHEN THE SUN IS OVERHEAD)
C11FORMAT = E12.5
C#.#####E+##
  .15000E+02
C12NEXT 6 LINES CONTAIN LOS GEOMETRY INFORMATION
C12LINE 12 CONTAINS IPATH AND ICASE
C12FORMAT = I4,2X,I4
C12#  ####
   4    5
C13LINE 13 CONTAINS H1ALT, H1LONG AND H1LAT
C13FORMAT = 3(E12.7,2X)
C13#####E+##  .#######E+##  .#######E+##
.7000000E+02  .6200000E+02  .5000000E+02
C14LINE 14 CONTAINS H2ALT, H2LONG AND H2LAT
C14FORMAT = 3(E12.7,2X)
C14#####E+##  .#######E+##  .#######E+##
.2900000E+03  .6200000E+02  .7000000E+02
C15LINE 15 CONTAINS RANGE,BETA,A0
C15FORMAT = 3(E13.8,1x)
C15######E+## .########E+## .########E+##
 .6000000E+02  .1200000E+03  .0000000E+00
C16LINE 16 CONTAINS B0,HMIN,LEN
C16FORMAT = 2(E13.8,1x),I4
C16######E+## .########E+## ####
 .9000000E+02  .1000000E+03    0
C17Line 17 CONTAINS TIME,IDAY,ICASES
C17TIME IS GMT TIME (0. TO 24.)
C17IDAY IS FROM 1 TO 366
C17THESE OPTIONS ARE NOT USED IN SHARC-1
C17FORMAT = E12.7,2X,2I4
C17#####E+##  #### ###
.0000000E+00     6   1
C18SPECTRAL INFORMATION IN CM-1
C18 WMIN,WMAX,BINRES(RESOLUTION),IRELAY=1 FOR RELAYERING
C18FORMAT = 2X,3(E12.5,2X),I2,2X,E12.5
C18#.#####E+##  ##.#####E+##  ##.#####E+##  ##
    .19000E+04    .45000E+04    .10000E+01   1
C19 OUTPUT CONTROL PARAMETERS:
C19 1) MODEL ATMOSPHERE OUTPUT ==>1 FOR FULL LISTING
C19 2) ATMOSPHERIC MOLECULE IDENTIFICATION == >2 FOR TABLE
C19 3) MOLECULAR RADIATORS INFORMATION ==>2 FOR ECHO OF INPUTS
C19 4) NOT CURRENTLY USED
C19 5) SELECTED TRANSITIONS ==>1 FOR TRANSITIONS SELECTED
C19 6) MOLECULAR BAND INFORMATION ==>2 FOR ECHO OF BAND INFORMATION
C19 7) NEMESIS OUTPUT ==>1 NEMESIS ONLY ==2 FOR POST POPULATIONS
C19 8) FINAL STATE POPULATIONS ==>1 YES
```

```
C19 9) FINAL VIBRATIONAL TEMPERATURES ==>1 YES
C19 10)LOS OUTPUT ==>1 FOR COLUMN DENSITIES
C19 11)CURRENTLY NOT USED
C19 12)SPECTRAL RADIANCE OUTPUT ==>1 FOR RADIANCE OUTPUT IN GENERAL
C19    OUTPUT FILE  SPECTRAL INFORMATION IS ALWAYS PLACED IN SPEC.OUT
C19 FORMAT = 12(2X,I2)
C  1   2   3   4   5   6   7   8   9  10  11  12
C ##  ##  ##  ##  ##  ##  ##  ##  ##  ##  ##  ##
   1   2   2   0   1   2   2   1   1   1   0   1
C20 SAVED POPULATIONS FILE NAME AND ISAVE
C20 WHEN ISAVE = 0 POPULATIONS ARE SAVED
C20 ISAVE = 1 SAVED POPULATIONS ARE USED FOR CALCULATION
C20 FORMAT=(2X,A20,2X,I4)
C2####################  ####
  CO45WIN.DAT              0
```

SHARC.INP for test 3, called SHARC3.INP in Appendix A.

```
CO FILE SHARC.INP
CO THIS FILE HOLDS THE DEFAULT VALUES FOR SHARC
CO THIS FILE IS UPDATED TO THE CURRENT VALUES OF THE PARAMETERS
CO EACH TIME SHARC IS RUN.
CO
C1 THE FIRST LINE CONTAINS THE INTERACTIVE/BATCH OPTION
C1 IF IT EQUALS 1, SHARC WILL RUN INTERACTIVELY, ALLOWING
C1 THE USER TO UPDATE OPTIONS.  IF IT EQUALS 0, SHARC WILL
C1 RUN IN BATCH MODE. THIS WILL NOT ALLOW THE USER TO UPDATE SHARC.INP.
C1 THIS FILE MUST BE EDITTED TO CHANGE THE VALUE OF THIS PARAMETER.
C1 FORMAT = I4
C1##
   1
C2 TITLE FOR CALCULATION   WILL APPEAR ON TOP OF GENERAL OUTPUT FILE
C2 FORMAT(1X,A68,I3)
C#################################################################### ###
 CO   NIGHT  WINTER  45-LATITUDE  SECOND RUN WITH NEW LOS                56
C3 LINE 2 CONTAINS THE VARIABLE IATMOS.
C3 THIS VARIABLE IS USED TO SELECT THE DESIRED MODEL ATMOSPHERE AND
C3 THE ATMOSPHERIC FILE NAME.
C3 FORMAT = I4,2X,A11
C3##  ###########
   7  SAT45WN.DAT
C4 LINE 3 CONTAINS THE EXO-ATMOSPHERIC TEMPERATURE AND
C4 A CONTROL PARAMETER WHICH SELECTS EITHER THE DAY(4) OR NIGHT(3)
C4 OPTION FOR THE MODEL ATMOSPHERE.
C4 FORMAT = E12.5,2X,A5
C4 #####E+##  #####
  .15000E+04  NIGHT
C5 NEMESIS CONTROL PARAMETERS
C5 WARNING: CHANGING THESE PARAMETERS WILL EFFECT THE ACCURACY
C5 OF THE MONTE CARLO SIMULATION.
C5 TOTAL NUMBER OF PHOTONS, MAXIMUM ORDER OF SCATTERING
C5 GLOBAL SUNSHINE AND EARTHSHINE PARAMETERS (1=YES , 0=NO)
C5 FORMAT=2X,6I,2X,6I,2x,I6,2X,I6
C5 #####  ######  ######  ######
   10000     200       0       1
C6 AFGL# FOR MOLECULE,LINKING FILE, STATE FILE, BAND FILE
C6 UP TO 5 RADIATORS H2O=1, CO2=2, O3=3, CO=5, NO=8
C6FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C6####  ###########  ###########  ###########
     5  COLINK.DAT   COSTAT.DAT   COBAND.DAT
C7 FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C7####  ###########  ###########  ###########
     0  NOLINK.DAT   NOSTAT.DAT   NOBAND.DAT
C8 FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C8 ###  ###########  ###########  ###########
     0  NOLINK.DAT   NOSTAT.DAT   NOBAND.DAT
C9 FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
```

```
C9 ###   ############   ############   ############
     0  NOLINK.DAT   NOSTAT.DAT   NOBAND.DAT
C10FORMAT=2X,I4,2X,11A1,2X,11A1,2X,11A1
C10###   ############   ############   ############
     0  NOLINK.DAT   NOSTAT.DAT   NOBAND.DAT
C11 SOLAR ZENITH ANGLE IN DEGREES. 0 FOR THE SUN OVERHEAD
C11( 0.0 WHEN THE SUN IS OVERHEAD)
C11FORMAT = E12.5
C#.#####E+##
  .15000E+02
C12NEXT 6 LINES CONTAIN LOS GEOMETRY INFORMATION
C12LINE 12 CONTAINS IPATH AND ICASE
C12FORMAT = I4,2X,I4
C12#  ####
   4     5
C13LINE 13 CONTAINS H1ALT, H1LONG AND H1LAT
C13FORMAT = 3(E12.7,2X)
C13#####E+##  .#######E+##  .#######E+##
.7000000E+02  .6200000E+02  .5000000E+02
C14LINE 14 CONTAINS H2ALT, H2LONG AND H2LAT
C14FORMAT = 3(E12.7,2X)
C14#####E+##  .#######E+##  .#######E+##
.2900000E+03  .6200000E+02  .7000000E+02
C15LINE 15 CONTAINS RANGE,BETA,A0
C15FORMAT = 3(E13.8,1x)
C15######E+## .########E+## .########E+##
 .6000000E+02  .1200000E+03  .0000000E+00
C16LINE 16 CONTAINS B0,HMIN,LEN
C16FORMAT = 2(E13.8,1x),I4
C16######E+## .########E+## ####
 .9000000E+02  .1500000E+03    0
C17Line 17 CONTAINS TIME,IDAY,ICASES
C17TIME IS GMT TIME (0. TO 24.)
C17IDAY IS FROM 1 TO 366
C17THESE OPTIONS ARE NOT USED IN SHARC-2
C17FORMAT = E12.7,2X,2I4
C17#####E+##  #### ###
.0000000E+00     6   1
C18SPECTRAL INFORMATION IN CM-1
C18 WMIN,WMAX,BINRES(RESOLUTION),IRELAY=1 FOR RELAYERING
C18FORMAT = 2X,3(E12.5,2X),I2,2X,E12.5
C18#.#####E+##  ##.#####E+##  ##.#####E+##  ##
    .19000E+04    .45000E+04    .10000E+01   1
C19 OUTPUT CONTROL PARAMETERS:
C19 1) MODEL ATMOSPHERE OUTPUT ==>1 FOR FULL LISTING
C19 2) ATMOSPHERIC MOLECULE IDENTIFICATION == >2 FOR TABLE
C19 3) MOLECULAR RADIATORS INFORMATION ==>2 FOR ECHO OF INPUTS
C19 4) NOT CURRENTLY USED
C19 5) SELECTED TRANSITIONS ==>1 FOR TRANSITIONS SELECTED
C19 6) MOLECULAR BAND INFORMATION ==>2 FOR ECHO OF BAND INFORMATION
C19 7) NEMESIS OUTPUT ==>1 NEMESIS ONLY ==2 FOR POST POPULATIONS
C19 8) FINAL STATE POPULATIONS ==>1 YES
```

```
C19 9) FINAL VIBRATIONAL TEMPERATURES ==>1 YES
C19 10)LOS OUTPUT ==>1 FOR COLUMN DENSITIES
C19 11)CURRENTLY NOT USED
C19 12)SPECTRAL RADIANCE OUTPUT ==>1 FOR RADIANCE OUTPUT IN GENERAL
C19    OUTPUT FILE  SPECTRAL INFORMATION IS ALWAYS PLACED IN SPEC.OUT
C19 FORMAT = 12(2X,I2)
C  1   2   3   4   5   6   7   8   9  10  11  12
C ##  ##  ##  ##  ##  ##  ##  ##  ##  ##  ##  ##
   1   0   0   0   1   0   0   1   1   1   0   0
C20 SAVED POPULATIONS FILE NAME AND ISAVE
C20 WHEN ISAVE = 0 POPULATIONS ARE SAVED
C20 ISAVE = 1 SAVED POPULATIONS ARE USED FOR CALCULATION
C20 FORMAT=(2X,A20,2X,I4)
C2####################  ####
  CO45WIN.DAT             1
```

APPENDIX F

TEST CASE -- OUTPUTS

The general SHARC output file is called SHARC.OUT. This appendix includes the output for the input files given in Appendix E. The output should be printed on 132 column paper, or at 17 characters per inch on 8.5 inch paper.

Output file for first test case.

```
         SSSSSS   HH    HH     AAAAAA     RRRRRR        CCCCCC
       SS        HH    HH    AA    AA    RR    RR     CC
      SS        HH    HH    AA    AA    RR    RR     CC
      SSSSS    HHHHHHHH    AAAAAAAA    RRRRRRR     CC
         SS   HH    HH    AA    AA    RR   RR     CC
        SS   HH    HH    AA    AA    RR     RR   CC
  SSSSSS    HH    HH    AA    AA    RR      RR  CCCCCC
```

STRATEGIC HIGH-ALTITUDE RADIANCE CODE

VERSION 1.0

********** CO, CO2, NO, H2O, O3 DAYTIME 1976 STANDARD ATMOSPHERE **********

Fri Feb 3 15:59:00 1989

ATMOSPHERIC PROFILE

ATMOSPHERE FILE NAME: SAT1976.DAT
NUMBER OF LAYERS: 60
EXOATMOSPHERIC TEMPERATURE(K): 1000.0
DAY-NIGHT PARAMETER: DAY

ALT(KM)	TEMP(K)	TOTAL NUMBER DENSITY(MOLEC/CM3)									
		O2	O	CH4	CO2	H2O	NO	N2O	CO	N2	O3
60.0	247.1	.135E+16	.120E+11	.603E+14	.203E+13	.312E+11	.900E+08	.645E+11	.904E+09	.504E+16	.733E
62.0	241.0	.105E+16	.133E+11	.469E+14	.158E+13	.238E+11	.720E+08	.502E+11	.100E+10	.392E+16	.440E
64.0	236.1	.812E+15	.147E+11	.362E+14	.122E+13	.181E+11	.580E+08	.388E+11	.109E+10	.303E+16	.240E
66.0	230.6	.624E+15	.163E+11	.278E+14	.936E+12	.134E+11	.460E+08	.298E+11	.119E+10	.233E+16	.110E
68.0	225.1	.477E+15	.181E+11	.213E+14	.715E+12	.101E+11	.370E+08	.228E+11	.123E+10	.178E+16	.520E
70.0	219.6	.362E+15	.200E+11	.161E+14	.542E+12	.734E+10	.290E+08	.173E+11	.121E+10	.135E+16	.200E
72.0	214.3	.273E+15	.249E+11	.122E+14	.408E+12	.531E+10	.230E+08	.130E+11	.125E+10	.102E+16	.900E
74.0	210.4	.203E+15	.310E+11	.904E+13	.304E+12	.371E+10	.180E+08	.968E+10	.126E+10	.755E+15	.460E
76.0	206.4	.150E+15	.387E+11	.668E+13	.225E+12	.256E+10	.140E+08	.716E+10	.122E+10	.559E+15	.270E
78.0	202.5	.110E+15	.482E+11	.492E+13	.165E+12	.175E+10	.115E+08	.526E+10	.116E+10	.411E+15	.190E
80.0	198.6	.807E+14	.600E+11	.360E+13	.121E+12	.116E+10	.960E+07	.385E+10	.116E+10	.301E+15	.180E
82.0	194.7	.586E+14	.676E+11	.261E+13	.879E+11	.723E+09	.870E+07	.280E+10	.118E+10	.219E+15	.220E
84.0	190.8	.424E+14	.763E+11	.189E+13	.635E+11	.438E+09	.820E+07	.202E+10	.111E+10	.158E+15	.380E
86.0	186.9	.304E+14	.860E+11	.136E+13	.456E+11	.266E+09	.870E+07	.145E+10	.113E+10	.113E+15	.450E
88.0	186.9	.213E+14	.151E+12	.950E+12	.319E+11	.153E+09	.105E+08	.102E+10	.107E+10	.794E+14	.450E
90.0	186.9	.149E+14	.244E+12	.666E+12	.224E+11	.891E+08	.140E+08	.713E+09	.107E+10	.557E+14	.380E
92.0	187.0	.105E+14	.343E+12	.466E+12	.157E+11	.479E+08	.180E+08	.499E+09	.105E+10	.390E+14	.280E
94.0	187.7	.731E+13	.416E+12	.326E+12	.110E+11	.262E+08	.230E+08	.349E+09	.977E+09	.273E+14	.200E
96.0	189.3	.510E+13	.447E+12	.227E+12	.764E+10	.132E+08	.300E+08	.243E+09	.876E+09	.190E+14	.140E
98.0	191.7	.356E+13	.448E+12	.159E+12	.533E+10	.566E+07	.360E+08	.170E+09	.781E+09	.133E+14	.900E
100.0	195.1	.248E+13	.430E+12	.111E+12	.372E+10	.247E+07	.400E+08	.118E+09	.711E+09	.925E+13	.500E
102.0	199.5	.173E+13	.401E+12	.773E+11	.260E+10	.138E+07	.420E+08	.828E+08	.580E+09	.647E+13	.350E
104.0	205.3	.122E+13	.362E+12	.542E+11	.182E+10	.870E+06	.440E+08	.580E+08	.464E+09	.453E+13	.245E
106.0	212.9	.855E+12	.319E+12	.381E+11	.128E+10	.561E+06	.450E+08	.408E+08	.367E+09	.319E+13	.172E
108.0	223.3	.602E+12	.275E+12	.268E+11	.902E+09	.371E+06	.440E+08	.287E+08	.276E+09	.224E+13	.121E
110.0	240.0	.421E+12	.230E+12	.188E+11	.631E+09	.251E+06	.430E+08	.201E+08	.201E+09	.157E+13	.848E
112.0	264.0	.286E+12	.189E+12	.119E+11	.385E+09	.194E+06	.420E+08	.139E+08	.142E+09	.111E+13	.499E
114.0	288.0	.202E+12	.156E+12	.783E+10	.246E+09	.153E+06	.400E+08	.996E+07	.103E+09	.805E+12	.308E
116.0	312.0	.146E+12	.130E+12	.534E+10	.162E+09	.123E+06	.390E+08	.732E+07	.770E+08	.601E+12	.198E
118.0	336.0	.108E+12	.110E+12	.375E+10	.111E+09	.101E+06	.370E+08	.551E+07	.587E+08	.458E+12	.131E
120.0	360.0	.820E+11	.928E+11	.269E+10	.775E+08	.838E+05	.360E+08	.423E+07	.456E+08	.356E+12	.893E
122.0	383.5	.633E+11	.799E+11	.198E+10	.556E+08	.704E+05	.348E+08	.330E+07	.361E+08	.282E+12	.625E
124.0	406.2	.497E+11	.688E+11	.149E+10	.407E+08	.600E+05	.336E+08	.262E+07	.290E+08	.226E+12	.448E
126.0	428.0	.396E+11	.598E+11	.113E+10	.304E+08	.516E+05	.324E+08	.211E+07	.236E+08	.185E+12	.327E
128.0	449.0	.320E+11	.526E+11	.880E+09	.231E+08	.448E+05	.312E+08	.173E+07	.195E+08	.152E+12	.244E
130.0	469.3	.262E+11	.462E+11	.691E+09	.178E+08	.392E+05	.300E+08	.142E+07	.162E+08	.127E+12	.184E
132.0	488.4	.216E+11	.413E+11	.550E+09	.139E+08	.346E+05	.287E+08	.119E+07	.137E+08	.107E+12	.141E
134.0	507.5	.180E+11	.370E+11	.441E+09	.109E+08	.307E+05	.274E+08	.997E+06	.116E+08	.904E+11	.109E
136.0	525.2	.151E+11	.333E+11	.358E+09	.871E+07	.274E+05	.262E+08	.845E+06	.990E+07	.773E+11	.853E
138.0	542.9	.128E+11	.302E+11	.292E+09	.700E+07	.246E+05	.251E+08	.720E+06	.851E+07	.664E+11	.673E
140.0	559.3	.109E+11	.273E+11	.241E+09	.567E+07	.221E+05	.240E+08	.618E+06	.736E+07	.575E+11	.537E
142.0	575.7	.929E+10	.250E+11	.200E+09	.462E+07	.200E+05	.228E+08	.533E+06	.640E+07	.499E+11	.431E
144.0	591.0	.800E+10	.228E+11	.167E+09	.380E+07	.182E+05	.216E+08	.462E+06	.559E+07	.437E+11	.349E

146.0	606.2	.691E+10	.209E+11	.140E+09	.314E+07	.166E+05	.205E+08	.402E+06	.491E+07	.383E+11	.284E
148.0	620.3	.601E+10	.193E+11	.118E+09	.261E+07	.152E+05	.195E+08	.352E+06	.433E+07	.338E+11	.232E
150.0	634.4	.524E+10	.178E+11	.999E+08	.218E+07	.139E+05	.185E+08	.309E+06	.383E+07	.299E+11	.191E
160.0	696.3	.278E+10	.124E+11	.464E+08	.944E+06	.934E+04	.135E+08	.170E+06	.217E+07	.170E+11	.775E
170.0	747.6	.158E+10	.900E+10	.233E+08	.444E+06	.658E+04	.881E+07	.993E+05	.131E+07	.102E+11	.343E
180.0	790.1	.937E+09	.675E+10	.123E+08	.222E+06	.479E+04	.575E+07	.608E+05	.826E+06	.644E+10	.162E
190.0	825.3	.577E+09	.518E+10	.680E+07	.116E+06	.359E+04	.368E+07	.385E+05	.537E+06	.419E+10	.799E
200.0	854.6	.365E+09	.405E+10	.388E+07	.626E+05	.273E+04	.235E+07	.250E+05	.359E+06	.280E+10	.410E
210.0	876.8	.237E+09	.324E+10	.227E+07	.348E+05	.211E+04	.160E+07	.166E+05	.244E+06	.191E+10	.216E
220.0	899.0	.155E+09	.258E+10	.135E+07	.196E+05	.165E+04	.109E+07	.112E+05	.168E+06	.131E+10	.116E
230.0	907.4	.104E+09	.209E+10	.821E+06	.114E+05	.131E+04	.743E+06	.768E+04	.119E+06	.926E+09	.642E
240.0	915.8	.703E+08	.170E+10	.504E+06	.665E+04	.105E+04	.506E+06	.530E+04	.839E+05	.655E+09	.357E
250.0	933.4	.472E+08	.139E+10	.308E+06	.388E+04	.829E+03	.345E+06	.365E+04	.592E+05	.462E+09	.199E
260.0	951.0	.320E+08	.115E+10	.191E+06	.229E+04	.661E+03	.244E+06	.253E+04	.420E+05	.328E+09	.112E
270.0	957.2	.221E+08	.947E+09	.120E+06	.138E+04	.535E+03	.173E+06	.179E+04	.303E+05	.237E+09	.645E
280.0	963.5	.153E+08	.784E+09	.762E+05	.834E+03	.434E+03	.123E+06	.127E+04	.220E+05	.172E+09	.373E
290.0	969.8	.106E+08	.653E+09	.484E+05	.507E+03	.352E+03	.868E+05	.901E+03	.160E+05	.125E+09	.217E
300.0	976.0	.743E+07	.543E+09	.309E+05	.310E+03	.287E+03	.615E+05	.642E+03	.116E+05	.909E+08	.127E

H2O RADIATIVE PROPERTIES

STATE	ENERGY(CM-1)	DEGENERACY
H2O(000)	.000	1.
H2O(010)	1594.750	1.
H2O(020)	3151.630	1.
H2O(100)	3657.053	1.
H2O(001)	3755.930	1.
H2O(030)	4666.793	1.
H2O(110)	5234.977	1.
H2O(011)	5331.269	1.

TRANSITION		FREQUENCY(CM-1)	ESHINE T(K)	RADIANCE
H2O(010)	-H2O(000)	1594.750	260.0	Y
H2O(020)	-H2O(000)	3151.630	270.0	Y
H2O(100)	-H2O(000)	3657.053	260.0	Y
H2O(001)	-H2O(000)	3755.930	260.0	Y
H2O(030)	-H2O(000)	4666.793	280.0	Y
H2O(110)	-H2O(000)	5234.977	280.0	Y
H2O(011)	-H2O(000)	5331.269	270.0	Y
H2O(020)	-H2O(010)	1556.880	230.0	Y
H2O(100)	-H2O(010)	2062.303	250.0	Y
H2O(001)	-H2O(010)	2161.180	250.0	Y
H2O(030)	-H2O(010)	3072.043	280.0	Y
H2O(110)	-H2O(010)	3640.227	250.0	Y
H2O(011)	-H2O(010)	3736.519	250.0	Y
H2O(030)	-H2O(020)	1515.163	240.0	Y

EXCITED STATE NUMBER DENSITIES(MOLEC/CM3)

ALT(KM)	H2O(000)	H2O(010)	H2O(020)	H2O(100)	H2O(001)	H2O(030)	H2O(110)	H2O(011)
61.0	.275E+11	.231E+07	.628E+04	.514E+03	.311E+04	.166E+01	.848E-01	.308E+00
63.0	.210E+11	.143E+07	.619E+04	.485E+03	.313E+04	.139E+01	.698E-01	.249E+00
65.0	.158E+11	.862E+06	.600E+04	.451E+03	.307E+04	.114E+01	.571E-01	.197E+00
67.0	.117E+11	.515E+06	.573E+04	.415E+03	.297E+04	.936E+00	.470E-01	.155E+00
69.0	.870E+10	.307E+06	.541E+04	.380E+03	.284E+04	.768E+00	.393E-01	.122E+00
71.0	.633E+10	.182E+06	.498E+04	.342E+03	.265E+04	.627E+00	.330E-01	.949E-01
73.0	.451E+10	.111E+06	.445E+04	.304E+03	.243E+04	.520E+00	.283E-01	.758E-01
75.0	.314E+10	.706E+05	.382E+04	.265E+03	.216E+04	.432E+00	.246E-01	.617E-01
77.0	.216E+10	.462E+05	.318E+04	.228E+03	.189E+04	.358E+00	.215E-01	.506E-01
79.0	.146E+10	.311E+05	.252E+04	.193E+03	.159E+04	.292E+00	.187E-01	.416E-01
81.0	.939E+09	.211E+05	.185E+04	.156E+03	.126E+04	.227E+00	.158E-01	.336E-01
83.0	.581E+09	.143E+05	.125E+04	.122E+03	.942E+03	.167E+00	.130E-01	.264E-01
85.0	.352E+09	.976E+04	.789E+03	.940E+02	.674E+03	.119E+00	.106E-01	.207E-01
87.0	.209E+09	.672E+04	.465E+03	.728E+02	.464E+03	.804E-01	.871E-02	.161E-01
89.0	.121E+09	.451E+04	.253E+03	.558E+02	.303E+03	.511E-01	.706E-02	.120E-01
91.0	.685E+08	.290E+04	.129E+03	.420E+02	.189E+03	.305E-01	.558E-02	.846E-02
93.0	.370E+08	.174E+04	.602E+02	.300E+02	.110E+03	.168E-01	.417E-02	.547E-02
95.0	.197E+08	.101E+04	.269E+02	.209E+02	.618E+02	.888E-02	.303E-02	.335E-02
97.0	.942E+07	.516E+03	.106E+02	.129E+02	.308E+02	.416E-02	.194E-02	.179E-02
99.0	.406E+07	.234E+03	.369E+01	.699E+01	.137E+02	.173E-02	.109E-02	.837E-03
101.0	.192E+07	.115E+03	.140E+01	.404E+01	.662E+01	.790E-03	.651E-03	.421E-03
103.0	.113E+07	.689E+02	.651E+00	.280E+01	.393E+01	.445E-03	.465E-03	.257E-03
105.0	.716E+06	.447E+02	.328E+00	.204E+01	.253E+01	.272E-03	.350E-03	.169E-03
107.0	.466E+06	.295E+02	.169E+00	.148E+01	.166E+01	.172E-03	.261E-03	.113E-03
109.0	.311E+06	.200E+02	.901E-01	.107E+01	.111E+01	.111E-03	.195E-03	.767E-04
111.0	.223E+06	.146E+02	.518E-01	.818E+00	.799E+00	.778E-04	.155E-03	.562E-04
113.0	.174E+06	.116E+02	.333E-01	.668E+00	.625E+00	.596E-04	.132E-03	.450E-04
115.0	.138E+06	.951E+01	.227E-01	.549E+00	.499E+00	.469E-04	.114E-03	.369E-04
117.0	.112E+06	.789E+01	.162E-01	.455E+00	.405E+00	.377E-04	.984E-04	.307E-04
119.0	.924E+05	.666E+01	.120E-01	.381E+00	.334E+00	.309E-04	.859E-04	.260E-04
121.0	.771E+05	.568E+01	.923E-02	.321E+00	.279E+00	.256E-04	.754E-04	.222E-04
123.0	.652E+05	.491E+01	.731E-02	.274E+00	.236E+00	.216E-04	.666E-04	.192E-04
125.0	.558E+05	.427E+01	.594E-02	.236E+00	.202E+00	.184E-04	.589E-04	.167E-04
127.0	.482E+05	.375E+01	.492E-02	.205E+00	.174E+00	.159E-04	.524E-04	.147E-04
129.0	.420E+05	.331E+01	.415E-02	.179E+00	.152E+00	.138E-04	.468E-04	.130E-04
131.0	.369E+05	.293E+01	.354E-02	.158E+00	.134E+00	.121E-04	.418E-04	.115E-04
133.0	.326E+05	.261E+01	.306E-02	.140E+00	.118E+00	.107E-04	.375E-04	.103E-04
135.0	.290E+05	.233E+01	.267E-02	.125E+00	.105E+00	.954E-05	.337E-04	.916E-05
137.0	.260E+05	.209E+01	.236E-02	.112E+00	.940E-01	.853E-05	.303E-04	.821E-05
139.0	.234E+05	.189E+01	.209E-02	.101E+00	.845E-01	.766E-05	.274E-04	.743E-05
141.0	.211E+05	.170E+01	.187E-02	.910E-01	.763E-01	.691E-05	.247E-04	.667E-05
143.0	.191E+05	.155E+01	.168E-02	.826E-01	.692E-01	.626E-05	.224E-04	.607E-05
145.0	.174E+05	.140E+01	.151E-02	.752E-01	.629E-01	.569E-05	.203E-04	.549E-05
147.0	.159E+05	.127E+01	.137E-02	.686E-01	.575E-01	.519E-05	.185E-04	.499E-05
149.0	.145E+05	.117E+01	.125E-02	.629E-01	.526E-01	.475E-05	.169E-04	.459E-05
155.0	.116E+05	.923E+00	.984E-03	.503E-01	.421E-01	.379E-05	.133E-04	.362E-05
165.0	.796E+04	.613E+00	.663E-03	.345E-01	.288E-01	.259E-05	.872E-05	.240E-05
175.0	.569E+04	.424E+00	.469E-03	.247E-01	.206E-01	.185E-05	.592E-05	.166E-05
185.0	.419E+04	.302E+00	.343E-03	.182E-01	.152E-01	.136E-05	.416E-05	.118E-05

195.0	315E+04	.221E+00	.257E-03	.137E-01	.114E-01	.102E-05	.301E-05	.864E-06
205.0	.242E+04	.168E+00	.196E-03	.105E-01	.875E-02	.783E-06	.223E-05	.653E-06
215.0	.188E+04	.128E+00	.152E-03	.816E-02	.680E-02	.608E-06	.169E-05	.500E-06
225.0	.148E+04	.978E-01	.120E-03	.642E-02	.535E-02	.478E-06	.129E-05	.381E-06
235.0	.118E+04	.786E-01	.952E-04	.512E-02	.426E-02	.381E-06	.102E-05	.305E-06
245.0	.937E+03	.640E-01	.758E-04	.407E-02	.340E-02	.303E-06	.807E-06	.248E-06
255.0	.745E+03	.483E-01	.601E-04	.324E-02	.270E-02	.240E-06	.628E-06	.188E-06
265.0	.598E+03	.387E-01	.482E-04	.260E-02	.216E-02	.193E-06	.500E-06	.151E-06
275.0	.484E+03	.294E-01	.390E-04	.210E-02	.175E-02	.156E-06	.396E-06	.115E-06
285.0	.393E+03	.233E-01	.316E-04	.171E-02	.142E-02	.126E-06	.318E-06	.917E-07
295.0	.320E+03	.189E-01	.257E-04	.139E-02	.116E-02	.103E-06	.258E-06	.746E-07

VIBRATIONAL TEMPERATURES(K)

ALT(KM)	KINETIC	H2O(010)	H2O(020)	H2O(100)	H2O(001)	H2O(030)	H2O(110)	H2O(011)
61.0	244.3	244.5	296.5	295.7	337.8	285.4	284.2	304.2
63.0	238.8	239.1	301.6	299.3	343.8	286.5	285.0	304.9
65.0	233.3	233.8	306.8	302.9	349.8	287.6	285.9	305.6
67.0	227.8	228.7	312.0	306.7	355.7	288.8	287.0	306.2
69.0	222.3	223.8	317.3	310.5	361.8	290.0	288.3	306.9
71.0	216.9	219.4	322.6	314.4	368.0	291.5	289.9	307.8
73.0	212.3	216.3	327.9	318.6	374.4	293.4	292.0	309.2
75.0	208.4	214.4	333.0	323.1	380.9	295.7	294.5	311.2
77.0	204.5	213.4	337.7	327.6	387.4	298.2	297.3	313.4
79.0	200.6	213.4	341.8	332.2	393.7	300.7	300.3	316.0
81.0	196.7	214.3	345.2	337.1	399.7	303.2	303.6	318.9
83.0	192.7	216.2	347.5	342.2	405.3	305.7	307.1	322.1
85.0	188.8	218.7	348.6	347.6	410.5	307.8	310.9	325.6
87.0	186.9	221.8	348.4	353.8	415.1	309.7	315.1	329.4
89.0	186.9	225.0	346.8	360.7	419.0	311.1	319.7	333.0
91.0	186.9	227.9	343.9	367.8	422.2	311.8	324.2	336.2
93.0	187.4	230.3	340.2	375.2	424.6	312.1	328.8	338.9
95.0	188.5	232.3	335.8	382.6	426.5	312.0	333.3	341.0
97.0	190.5	233.8	331.0	389.7	427.9	311.7	337.7	342.7
99.0	193.4	235.0	326.0	396.4	428.9	311.2	341.7	343.9
101.0	197.3	235.9	320.8	402.5	429.6	310.7	345.4	344.8
103.0	202.4	236.5	315.7	407.7	430.1	310.1	348.6	345.5
105.0	209.1	237.0	310.7	412.1	430.5	309.6	351.3	346.0
107.0	218.1	237.4	305.8	415.6	430.7	309.1	353.6	346.4
109.0	231.6	237.7	301.2	418.3	430.9	308.7	355.5	346.7
111.0	252.0	238.2	296.9	420.5	431.0	308.4	357.2	347.1
113.0	276.0	238.8	293.2	422.0	431.1	308.1	358.7	347.5
115.0	300.0	239.4	290.2	423.1	431.2	307.9	360.1	348.0
117.0	324.0	240.0	287.9	423.8	431.2	307.8	361.2	348.4
119.0	348.0	240.6	286.0	424.4	431.2	307.7	362.2	348.8
121.0	371.8	241.1	284.5	424.8	431.3	307.7	363.1	349.2
123.0	394.9	241.7	283.3	425.0	431.3	307.6	363.8	349.5
125.0	417.1	242.1	282.4	425.3	431.3	307.6	364.4	349.8
127.0	438.5	242.5	281.7	425.4	431.3	307.6	364.9	350.1
129.0	459.2	242.8	281.1	425.6	431.3	307.5	365.4	350.3
131.0	478.8	243.0	280.6	425.7	431.3	307.5	365.7	350.4
133.0	497.9	243.2	280.2	425.7	431.3	307.5	365.9	350.6
135.0	516.3	243.3	279.9	425.8	431.3	307.5	366.1	350.6
137.0	534.0	243.4	279.6	425.9	431.3	307.5	366.2	350.7
139.0	551.1	243.6	279.4	425.9	431.3	307.5	366.3	350.8
141.0	567.5	243.4	279.2	425.9	431.3	307.5	366.3	350.7
143.0	583.3	243.5	279.1	426.0	431.3	307.5	366.3	350.7
145.0	598.6	243.4	278.9	426.0	431.3	307.4	366.2	350.7
147.0	613.2	243.2	278.8	426.0	431.3	307.4	366.1	350.6
149.0	627.3	243.4	278.7	426.0	431.3	307.4	366.1	350.6
155.0	665.3	243.0	278.5	426.1	431.3	307.4	365.9	350.4
165.0	721.9	242.2	278.2	426.1	431.3	307.4	365.1	349.9
175.0	768.8	241.4	278.0	426.1	431.3	307.3	364.2	349.4
185.0	807.7	240.6	277.9	426.2	431.3	307.3	363.3	348.8

195.0	839.9	239.9	277.8	426.2	431.3	307.3	362.6	348.4
205.0	865.7	239.6	277.8	426.2	431.3	307.3	362.1	348.1
215.0	887.9	239.3	277.7	426.2	431.3	307.3	361.6	347.9
225.0	903.2	238.4	277.7	426.2	431.3	307.3	361.1	347.4
235.0	911.6	238.7	277.7	426.2	431.3	307.3	360.9	347.5
245.0	924.6	239.2	277.7	426.2	431.4	307.3	360.9	347.8
255.0	942.2	238.0	277.6	426.2	431.3	307.2	360.5	347.1
265.0	954.1	237.9	277.6	426.2	431.3	307.2	360.4	347.1
275.0	960.4	236.3	277.6	426.2	431.3	307.2	360.0	346.2
285.0	966.6	235.7	277.6	426.2	431.3	307.2	359.8	345.9
295.0	972.9	235.7	277.6	426.2	431.4	307.2	359.8	345.9

CO2 RADIATIVE PROPERTIES

STATE	ENERGY(CM-1)	DEGENERACY
CO2(00001)	.000	1.
CO2(01101)	667.380	2.
CO2(10002)	1285.409	1.
CO2(02201)	1335.132	2.
CO2(10001)	1388.185	1.
CO2(11102)	1932.470	2.
CO2(03301)	2003.246	2.
CO2(11101)	2076.856	2.
CO2(00011)	2349.143	1.
CO2(20003)	2548.366	1.
CO2(20002)	2671.143	1.
CO2(20001)	2797.135	1.
CO2(01111)	3004.012	2.
CO2(10012)	3612.842	1.
CO2(02211)	3659.273	2.
CO2(10011)	3714.783	[illegible]
CO2(20013)	4853.623	1.
CO2(04411)	4908.396	2.
CO2(20012)	4977.834	1.
CO2(20011)	5099.660	1.

TRANSITION	*FREQUENCY(CM-1)*	*ESHINE T(K)*	*RADIANCE*
CO2(01101)-CO2(00001)	667.380	260.0	Y
CO2(11102)-CO2(00001)	1932.470	240.0	Y
CO2(11101)-CO2(00001)	2076.856	240.0	Y
CO2(00011)-CO2(00001)	2349.143	250.0	Y
CO2(10012)-CO2(00001)	3612.842	260.0	Y
CO2(10011)-CO2(00001)	3714.783	260.0	Y
CO2(20013)-CO2(00001)	4853.623	230.0	Y
CO2(20012)-CO2(00001)	4977.834	240.0	Y
CO2(20011)-CO2(00001)	5[illegible]9.660	240.0	Y
CO2(10002)-CO2(01101)	618.029	250.0	Y
CO2(02201)-CO2(01101)	667.752	260.0	Y
CO2(10001)-CO2(01101)	720.805	260.0	Y
CO2(01111)-CO2(01101)	2336.632	260.0	Y
CO2(11102)-CO2(10002)	647.061	250.0	Y
CO2(11101)-CO2(10002)	791.447	230.0	Y
CO2(00011)-CO2(10002)	1063.734	230.0	Y
CO2(10012)-CO2(10002)	2327.433	250.0	Y
CO2(20013)-CO2(10002)	3568.214	250.0	Y
CO2(20012)-CO2(10002)	3692.425	250.0	Y
CO2(11102)-CO2(02201)	597.338	260.0	Y
CO2(03301)-CO2(02201)	668.114	250.0	Y
CO2(11101)-CO2(02201)	741.724	230.0	Y
CO2(02211)-CO2(02201)	2324.141	250.0	Y
CO2(11102)-CO2(10001)	544.285	230.0	Y
CO2(11101)-CO2(10001)	688.671	250.0	Y

CO2(00011)-CO2(10001)	960.958	230.0	Y
CO2(10011)-CO2(10001)	2326.598	250.0	Y
CO2(20012)-CO2(10001)	3589.649	250.0	Y
CO2(20011)-CO2(10001)	3711.475	250.0	Y

EXCITED STATE NUMBER DENSITIES(MOLEC/CM3)

ALT(KM)	CO2(00001)	CO2(01101)	CO2(10002)	CO2(02201)	CO2(10001)	CO2(11102)	CO2(03301)	CO2(11101)	CO2(00011)	CO2(20003)
	CO2(20002)	CO2(20001)	CO2(01111)	CO2(10012)	CO2(02211)	CO2(10011)	CO2(20013)	CO2(04411)	CO2(20012)	CO2(20011)
61.0	.173E+13	.676E+11	.903E+09	.135E+10	.493E+09	.407E+08	.268E+08	.174E+08	.128E+07	.100E+07
	.741E+06	.569E+06	.771E+04	.617E+04	.450E+04	340E+04	.115E+04	.182E+04	.120E+04	.111E+04
63.0	.135E+13	.481E+11	.576E+09	.853E+09	.310E+09	.243E+08	.158E+08	.102E+08	.799E+06	.804E+06
	.665E+06	.559E+06	.572E+04	.692E+04	.444E+04	.377E+04	.113E+04	.179E+04	.116E+04	.109E+04
65.0	.104E+13	.341E+11	.366E+09	.539E+09	.194E+09	.146E+08	.942E+07	.600E+07	.548E+06	.723E+06
	.649E+06	.581E+06	.642E+04	.789E+04	.433E+04	.424E+04	.110E+04	.175E+04	.113E+04	.107E+04
67.0	.801E+12	.238E+11	.228E+09	.333E+09	.119E+09	.876E+07	.558E+07	.352E+07	.526E+06	.707E+06
	.667E+06	.622E+06	.803E+04	.914E+04	.421E+04	.485E+04	.108E+04	.171E+04	.109E+04	.105E+04
69.0	.612E+12	.162E+11	.135E+09	.196E+09	.694E+08	.515E+07	.325E+07	.203E+07	.515E+06	.728E+06
	.704E+06	.675E+06	.985E+04	.107E+05	.408E+04	.559E+04	.105E+04	.167E+04	.105E+04	.102E+04
71.0	.464E+12	.112E+11	.800E+08	.115E+09	.405E+08	.313E+07	.194E+07	.120E+07	.488E+06	.772E+06
	.754E+06	.736E+06	.133E+05	.126E+05	.399E+04	.649E+04	.102E+04	.162E+04	.101E+04	.995E+03
73.0	.349E+12	.726E+10	.464E+08	.661E+08	.231E+08	.202E+07	.124E+07	.759E+06	.978E+06	.815E+06
	.794E+06	.784E+06	.155E+05	.147E+05	.386E+04	.751E+04	.990E+03	.158E+04	.976E+03	.968E+03
75.0	.259E+12	.544E+10	.312E+08	.441E+08	.153E+08	.151E+07	.916E+06	.557E+06	.132E+07	.841E+06
	.815E+06	.810E+06	.189E+05	.169E+05	.367E+04	.851E+04	.965E+03	.153E+04	.942E+03	.939E+03
77.0	.192E+12	.338E+10	.178E+08	.249E+08	.864E+07	.855E+06	.513E+06	.310E+06	.565E+06	.845E+06
	.810E+06	.813E+06	.172E+05	.183E+05	.323E+04	.917E+04	.939E+03	.148E+04	.904E+03	.908E+03
79.0	.141E+12	.227E+10	.116E+08	.161E+08	.557E+07	.650E+06	.385E+06	.231E+06	.104E+07	.813E+06
	.768E+06	.776E+06	.164E+05	.188E+05	.266E+04	.931E+04	.911E+03	.143E+04	.862E+03	.872E+03
81.0	.103E+12	.144E+10	.748E+07	.102E+08	.352E+07	.498E+06	.290E+06	.173E+06	.159E+07	.744E+06
	.688E+06	.701E+06	.131E+05	.180E+05	.201E+04	.883E+04	.880E+03	.136E+04	.815E+03	.831E+03
83.0	.748E+11	.891E+09	.479E+07	.640E+07	.222E+07	.319E+06	.183E+06	.109E+06	.124E+07	.643E+06
	.579E+06	.596E+06	.928E+04	.160E+05	.139E+04	.784E+04	.843E+03	.129E+04	.760E+03	.782E+03
85.0	.539E+11	.645E+09	.346E+07	.452E+07	.158E+07	.222E+06	.124E+06	.738E+05	.995E+06	.513E+06
	.447E+06	.464E+06	.726E+04	.134E+05	.890E+03	.654E+04	.801E+03	.120E+04	.698E+03	.725E+03
87.0	.383E+11	.427E+09	.234E+07	.298E+07	.106E+07	.137E+06	.751E+05	.451E+05	.646E+06	.303E+06
	.253E+06	.266E+06	.502E+04	.106E+05	.532E+03	.523E+04	.756E+03	.110E+04	.631E+03	.664E+03
89.0	.269E+11	.279E+09	.157E+07	.193E+07	.713E+06	.842E+05	.450E+05	.277E+05	.473E+06	.138E+06
	.109E+06	.116E+06	.334E+04	.802E+04	.299E+03	.403E+04	.708E+03	.982E+03	.557E+03	.595E+03
91.0	.188E+11	.188E+09	.109E+07	.128E+07	.494E+06	.540E+05	.278E+05	.178E+05	.404E+06	.635E+05
	.466E+05	.505E+05	.228E+04	.589E+04	.164E+03	.305E+04	.649E+03	.857E+03	.477E+03	.518E+03
93.0	.132E+11	.127E+09	.762E+06	.842E+06	.346E+06	345E+05	.169E+05	.114E+05	.284E+06	.315E+05
	.214E+05	.236E+05	.155E+04	.423E+04	.882E+02	.228E+04	.580E+03	.726E+03	.396E+03	.437E+03
95.0	.921E+10	.873E+08	.546E+06	.566E+06	.249E+06	.233E+05	.106E+05	.773E+04	.192E+06	.168E+05
	.106E+05	.119E+05	.106E+04	.299E+04	.471E+02	.169E+04	.504E+03	.596E+03	.318E+03	.357E+03
97.0	.642E+10	.613E+08	.402E+06	.390E+06	.185E+06	.167E+05	.702E+04	.561E+04	.145E+06	.945E+04
	.555E+04	.629E+04	.746E+03	.208E+04	.253E+02	.125E+04	.423E+03	.475E+03	249E+03	.283E+03
99.0	.448E+10	.422E+08	.295E+06	.266E+06	.138E+06	.122E+05	.465E+04	.415E+04	.103E+06	.538E+04
	.296E+04	.339E+04	.513E+03	.143E+04	.137E+02	.921E+03	.344E+03	.368E+03	.190E+03	.218E+03
101.0	.313E+10	.299E+08	.221E+06	.187E+06	.105E+06	.921E+04	.318E+04	.321E+04	.703E+05	.306E+04
	.159E+04	.184E+04	.362E+03	.983E+03	.767E+01	.677E+03	.271E+03	.278E+03	.141E+03	.164E+03
103.0	.219E+10	.214E+08	.167E+06	.134E+06	.804E+05	.713E+04	.224E+04	.25[illegible]E+04	.480E+05	.174E+04
	.865E+03	.101E+04	.258E+03	.673E+03	.443E+01	.496E+03	.208E+03	.207E+03	.104E+03	.122E+03
105.0	.154E+10	.155E+08	.127E+06	.978E+05	.626E+05	.563E+04	.164E+04	.208E+04	.337E+05	.988E+03
	.476E+03	.555E+03	.186E+03	.462E+03	.268E+01	.362E+03	.156E+03	.151E+03	.756E+02	.892E+02
107.0	.108E+10	.114E+08	.974E+05	.743E+05	.496E+05	.454E+04	.125E+04	.174E+04	.236E+05	.563E+03
	.265E+03	.308E+03	.138E+03	.319E+03	.172E+01	.264E+03	.116E+03	.109E+03	.546E+02	.647E+02

109.0	.758E+09	.873E+07	.767E+05	.603E+05	.406E+05	.382E+04	.104E+04	.154E+04	.163E+05	.320E+03
	.149E+03	.171E+03	.105E+03	.220E+03	.120E+01	.190E+03	.842E+02	.782E+02	.391E+02	.465E+02
111.0	.501E+09	.659E+07	.596E+05	.506E+05	.332E+05	.323E+04	.921E+03	.139E+04	.105E+05	.176E+03
	.818E+02	.900E+02	.791E+02	.144E+03	.897E+00	.129E+03	.573E+02	.522E+02	.264E+02	.313E+02
113.0	.311E+09	.469E+07	.438E+05	.405E+05	.255E+05	.259E+04	.785E+03	.119E+04	.631E+04	.986E+02
	.468E+02	.474E+02	.562E+02	.884E+02	.666E+00	.813E+02	.362E+02	.325E+02	.166E+02	.197E+02
115.0	.200E+09	.337E+07	.325E+05	.321E+05	.196E+05	.206E+04	.659E+03	.995E+03	.398E+04	.636E+02
	.314E+02	.287E+02	.404E+02	.569E+02	.508E+00	.531E+02	.237E+02	.210E+02	.108E+02	.128E+02
117.0	.134E+09	.246E+07	.243E+05	.254E+05	.152E+05	.164E+04	.547E+03	.822E+03	.260E+04	.459E+02
	.240E+02	.197E+02	.294E+02	.380E+02	.392E+00	.358E+02	.160E+02	.140E+02	.729E+01	.862E+01
119.0	.922E+08	.181E+07	.183E+05	.199E+05	.117E+05	.130E+04	.446E+03	.669E+03	.176E+04	.359E+02
	.198E+02	.151E+02	.216E+02	.262E+02	.303E+00	.248E+02	.111E+02	.962E+01	.506E+01	.596E+01
121.0	.651E+08	.134E+07	.139E+05	.154E+05	.900E+04	.102E+04	.357E+03	.536E+03	.123E+04	.291E+02
	.169E+02	.123E+02	.160E+02	.185E+02	.234E+00	.176E+02	.784E+01	.678E+01	.359E+01	.423E+01
123.0	.471E+08	.101E+07	.105E+05	.120E+05	.693E+04	.799E+03	.283E+03	.425E+03	.882E+03	.241E+02
	.145E+02	.104E+02	.120E+02	134E+02	.180E+00	.128E+02	.569E+01	.489E+01	.261E+01	.307E+01
125.0	.348E+08	.757E+06	.801E+04	.919E+04	.531E+04	.620E+03	.220E+03	.332E+03	.647E+03	.198E+02
	.124E+02	.875E+01	.906E+01	.989E+01	.138E+00	.946E+01	.421E+01	.360E+01	.193E+01	.227E+01
127.0	.262E+08	.576E+06	.613E+04	.707E+04	.409E+04	.482E+03	.171E+03	.258E+03	.484E+03	.163E+02
	.105E+02	.740E+01	.689E+01	.744E+01	.106E+00	.713E+01	.317E+01	.270E+01	.146E+01	.171E+01
129.0	.200E+08	.441E+06	.471E+04	.543E+04	.315E+04	.374E+03	.132E+03	.200E+03	.368E+03	.133E+02
	.874E+01	.620E+01	.527E+01	.568E+01	.813E-01	.545E+01	.243E+01	.205E+01	.111E+01	.131E+01
131.0	.155E+08	.340E+06	.364E+04	.418E+04	.243E+04	.291E+03	.101E+03	.155E+03	.284E+03	.108E+02
	.723E+01	.517E+01	.407E+01	.440E+01	.626E-01	.422E+01	.188E+01	.158E+01	.863E+00	.101E+01
133.0	.121E+08	.265E+06	.284E+04	.325E+04	.190E+04	.228E+03	.785E+02	.120E+03	.222E+03	.880E+01
	.601E+01	.432E+01	.318E+01	.344E+01	.486E-01	.331E+01	.147E+01	.124E+01	.676E+00	.795E+00
135.0	.961E+07	.208E+06	.222E+04	.252E+04	.148E+04	.179E+03	.606E+02	.934E+02	.175E+03	.712E+01
	.493E+01	.358E+01	.249E+01	.272E+01	.377E-01	.262E+01	.117E+01	.976E+00	.535E+00	.630E+00
137.0	.769E+07	.164E+06	.175E+04	.197E+04	.116E+04	.141E+03	.472E+02	.728E+02	.140E+03	.578E+01
	.406E+01	.297E+01	.197E+01	.218E+01	.294E-01	.210E+01	.933E+00	.778E+00	.428E+00	.504E+00
139.0	.620E+07	.130E+06	.139E+04	.154E+04	.919E+03	.112E+03	.366E+02	.569E+02	.113E+03	.467E+01
	.332E+01	.244E+01	.156E+01	.175E+01	.230E-01	.169E+01	.752E+00	.625E+00	.345E+00	.406E+00
141.0	.504E+07	.104E+06	.111E+04	.121E+04	.727E+03	.888E+02	.284E+02	.446E+02	.914E+02	.375E+01
	.269E+01	.200E+01	.125E+01	.142E+01	.181E-01	.137E+01	.611E+00	.507E+00	.280E+00	.330E+00
143.0	.413E+07	.836E+05	.885E+03	.955E+03	.577E+03	.707E+02	.223E+02	.350E+02	.748E+02	.305E+01
	.221E+01	.165E+01	.100E+01	.116E+01	.143E-01	.112E+01	.500E+00	.414E+00	.229E+00	.270E+00
145.0	.340E+07	.674E+05	.713E+03	.755E+03	.463E+03	.568E+02	.174E+02	.277E+02	.615E+02	.245E+01
	.180E+01	.135E+01	.808E+00	.958E+00	.113E-01	.926E+00	.411E+00	.340E+00	.188E+00	.222E+00
147.0	.282E+07	.547E+05	.578E+03	.601E+03	.372E+03	.456E+02	.137E+02	.220E+02	.510E+02	.200E+01
	.147E+01	.111E+01	.656E+00	.793E+00	.898E-02	.767E+00	.341E+00	.281E+00	.156E+00	.184E+00
149.0	.235E+07	.446E+05	.469E+03	.482E+03	.300E+03	.369E+02	.109E+02	.175E+02	.424E+02	.162E+01
	.121E+01	.917E+00	.535E+00	.660E+00	.721E-02	.639E+00	.284E+00	.233E+00	.130E+00	.153E+00
155.0	.153E+07	.275E+05	.287E+03	.282E+03	.182E+03	.222E+02	.618E+01	.102E+02	.277E+02	.986E+00
	.744E+00	.574E+00	.330E+00	.430E+00	.421E-02	.417E+00	.185E+00	.151E+00	.844E-01	.100E+00
165.0	.683E+06	.109E+05	.112E+03	.995E+02	.694E+02	.834E+01	.208E+01	.362E+01	.123E+02	.363E+00
	.280E+00	.220E+00	.130E+00	.190E+00	.148E-02	.185E+00	.821E-01	.667E-01	.374E-01	.445E-01
175.0	.328E+06	.465E+04	.478E+02	.385E+02	.291E+02	.343E+01	.755E+00	.143E+01	.589E+01	.141E+00
	.110E+00	.878E-01	.556E-01	.911E-01	.580E-03	.888E-01	.393E-01	.318E-01	.179E-01	.213E-01
185.0	.167E+06	.211E+04	.214E+02	.161E+02	.132E+02	.150E+01	.290E+00	.604E+00	.239E+01	.566E-01
	.448E-01	.362E-01	.253E-01	.461E-01	.232E-03	.450E-01	.199E-01	.161E-01	.904E-02	108E-01
195.0	.882E+05	.101E+04	.104E+02	.673E+01	.621E+01	.685E+00	.112E+00	.272E+00	.158E+01	.228E-01
	.182E-01	.148E-01	.121E-01	.243E-01	.989E-04	.238E-01	.105E-01	.846E-02	.477E-02	.571E-02

205.0	.482E+05	.506E+03	.497E+01	.291E+01	.291E+01	.312E+00	.438E-01	.122E+00	.861E+00	.920E-02
	.737E-02	.604E-02	.605E-02	.132E-01	.381E-04	.130E-01	.573E-02	.460E-02	.259E-02	.312E-02
215.0	.269E+05	.261E+03	.249E+01	.118E+01	.143E+01	.148E+00	.170E-01	.579E-01	.482E+00	.368E-02
	.296E-02	.244E-02	.310E-02	.737E-02	.146E-04	.724E-02	.320E-02	.256E-02	.145E-02	.174E-02
225.0	.154E+05	.139E+03	.128E+01	.541E+00	.749E+00	.747E-01	.748E-02	.291E-01	.275E+00	.165E-02
	.133E-02	.110E-02	.166E-02	.420E-02	.580E-05	.413E-02	.182E-02	.146E-02	.824E-03	.993E-03
235.0	.895E+04	.749E+02	.700E+00	.241E+00	.399E+00	.391E-01	.328E-02	.152E-01	.160E+00	.733E-03
	.589E-03	.490E-03	.874E-03	.244E-02	.203E-05	.240E-02	.106E-02	.848E-03	.478E-03	.577E-03
245.0	.523E+04	.408E+02	.387E+00	.111E+00	.223E+00	.213E-01	.150E-02	.825E-02	.933E-01	.340E-03
	.273E-03	.228E-03	.468E-03	.143E-02	.888E-06	.140E-02	.618E-03	.494E-03	.279E-03	.337E-03
255.0	.306E+04	.233E+02	.221E+00	.541E-01	.126E+00	.119E-01	.715E-03	.462E-02	.548E-01	.165E-03
	.133E-03	.112E-03	.262E-03	.837E-03	.433E-06	.820E-03	.362E-03	.289E-03	.163E-03	.197E-03
265.0	.182E+04	.126E+02	.127E+00	.254E-01	.718E-01	.667E-02	.336E-03	.259E-02	.326E-01	.790E-04
	.637E-04	.536E-04	.130E-03	.494E-03	.200E-06	.488E-03	.216E-03	.172E-03	.972E-04	.117E-03
275.0	.110E+04	.716E+01	.745E-01	.123E-01	.423E-01	.387E-02	.162E-03	.150E-02	.196E-01	.384E-04
	.309E-04	.261E-04	.658E-04	.296E-03	.985E-07	.293E-03	.130E-03	.104E-03	.586E-04	.709E-04
285.0	.667E+03	.421E+01	.445E-01	.672E-02	.252E-01	.229E-02	.856E-04	.890E-03	.118E-01	.204E-04
	.165E-04	.139E-04	.365E-04	.179E-03	.531E-07	.178E-03	.788E-04	.628E-04	.355E-04	.430E-04
295.0	.406E+03	.233E+01	.265E-01	.326E-02	.150E-01	.135E-02	.417E-04	.525E-03	.719E-02	.101E-04
	.810E-05	.685E-05	.205E-04	.109E-03	.257E-07	.108E-03	.480E-04	.383E-04	.216E-04	.262E-04

VIBRATIONAL TEMPERATURES(K)

ALT(KM)	KINETIC	CO2(01101)	CO2(10002)	CO2(02201)	CO2(10001)	CO2(11102)	CO2(03301)	CO2(11101)	CO2(00011)	CO2(20003)
	CO2(20002)	CO2(20001)	CO2(01111)	CO2(10012)	CO2(02211)	CO2(10011)	CO2(20013)	CO2(04411)	CO2(20012)	CO2(20011)
61.0	244.3	244.0	244.7	244.7	244.7	245.0	244.9	244.9	239.4	255.3
	262.1	269.6	216.9	267.2	257.3	266.6	330.4	330.5	339.5	346.6
63.0	238.8	238.6	238.4	238.4	238.4	239.4	239.3	239.3	235.7	255.8
	264.7	273.9	216.4	272.3	260.3	271.4	334.1	334.2	343.1	350.5
65.0	233.3	233.4	232.5	232.6	232.6	234.3	234.2	234.2	233.8	258.6
	269.0	279.5	220.6	278.0	263.4	276.7	337.9	338.0	346.9	354.6
67.0	227.8	228.2	226.5	226.5	226.6	229.5	229.4	229.4	237.4	263.0
	274.5	286.1	226.2	284.2	266.5	282.5	341.8	341.9	350.8	358.8
69.0	222.3	222.1	219.7	219.8	219.9	224.6	224.5	224.5	241.6	268.8
	281.0	293.4	231.9	291.0	269.7	288.7	345.9	346.0	354.9	363.1
71.0	216.9	217.4	213.4	213.5	213.7	220.6	220.4	220.4	245.5	275.6
	288.3	301.4	239.3	298.3	273.3	295.5	350.2	350.2	359.1	367.6
73.0	212.3	210.4	207.2	207.3	207.6	218.0	217.7	217.6	264.4	282.8
	295.8	309.5	245.2	306.1	276.9	302.8	354.9	354.8	363.7	372.4
75.0	208.4	210.8	205.0	205.0	205.2	218.1	217.6	217.4	277.3	290.2
	303.4	317.5	252.4	314.1	280.6	310.2	359.8	359.6	368.6	377.5
77.0	204.5	203.0	199.2	199.3	199.6	213.7	213.1	213.0	265.4	297.3
	310.6	325.3	255.4	321.6	283.2	317.1	365.0	364.6	373.6	382.8
79.0	200.6	199.2	196.7	196.6	197.0	214.2	213.4	213.2	286.1	304.0
	317.1	332.4	259.5	328.4	285.0	323.3	370.3	369.7	378.7	388.2
81.0	196.7	193.5	194.1	193.8	194.2	215.0	213.9	213.6	305.2	309.7
	322.5	338.3	260.8	334.0	285.4	328.5	375.9	375.0	383.9	393.7
83.0	192.7	187.4	191.5	191.0	191.6	212.9	211.7	211.4	307.0	314.4
	326.6	342.8	260.4	338.5	284.7	332.6	381.6	380.3	389.2	399.3
85.0	188.8	187.6	191.6	190.6	191.4	212.3	210.8	210.5	310.1	317.1
	328.5	345.1	261.7	341.9	282.9	335.6	387.4	385.5	394.4	404.9
87.0	186.9	185.0	190.6	189.1	190.3	210.1	208.3	208.3	307.5	312.1
	322.2	338.8	261.3	344.3	280.3	338.1	393.6	391.0	399.6	410.6
89.0	186.9	182.5	189.8	187.7	189.5	208.0	206.0	206.4	308.7	301.1
	309.4	325.7	260.5	346.0	277.0	340.2	400.1	396.4	404.8	416.3
91.0	186.9	181.1	189.6	186.6	189.4	206.6	204.1	205.1	314.4	291.0
	297.7	313.7	260.1	347.1	273.5	341.8	406.4	401.3	409.5	421.4
93.0	187.4	179.9	189.5	185.6	189.3	205.3	202.1	203.9	314.5	283.2
	288.3	304.1	259.5	347.7	269.8	343.3	412.2	405.7	413.5	426.0
95.0	188.5	179.4	190.0	184.9	189.9	204.7	200.6	203.5	313.6	277.5
	281.1	296.8	259.3	347.9	266.1	344.6	417.6	409.5	416.9	429.9
97.0	190.5	179.6	191.1	184.6	191.1	205.1	199.9	204.0	315.9	273.0
	275.3	290.8	259.4	347.8	262.7	345.9	422.3	412.6	419.7	433.2
99.0	193.4	179.2	192.1	184.2	192.2	205.8	199.2	204.9	316.4	268.9
	270.0	285.5	259.2	347.6	259.4	347.1	426.3	415.2	421.8	435.8
101.0	197.3	179.7	193.5	184.3	193.8	207.0	198.9	206.3	315.8	264.9
	265.2	280.5	259.3	347.2	256.6	348.3	429.5	417.2	423.5	437.8
103.0	202.4	180.4	195.0	184.7	195.6	208.6	199.0	208.1	315.1	261.0
	260.7	275.8	259.6	346.7	254.2	349.3	431.9	418.6	424.7	439.3
105.0	209.1	181.5	196.7	185.5	197.6	210.5	199.5	210.3	315.1	257.2
	256.5	271.3	260.1	346.2	252.4	350.3	433.8	419.7	425.6	440.4
107.0	218.1	183.2	198.6	186.9	200.0	212.7	200.7	213.0	314.9	253.4
	252.5	267.1	260.9	345.7	251.3	351.0	435.1	420.4	426.3	441.2

109.0	231.6	186.2	201.1	189.6	203.1	215.7	203.1	216.6	314.5	249.8
	248.9	262.9	262.2	345.3	251.3	351.7	436.1	420.9	426.9	441.8
111.0	252.0	191.1	204.6	194.2	207.5	219.9	207.3	221.6	313.7	246.7
	245.9	259.1	264.3	345.0	252.7	352.2	436.9	421.1	427.3	442.3
113.0	276.0	196.5	208.6	199.3	212.3	224.4	212.2	226.9	312.8	245.1
	244.7	256.4	266.5	344.9	254.9	352.6	437.4	421.2	427.7	442.7
115.0	300.0	201.0	211.9	203.6	216.4	228.3	216.4	231.5	312.2	245.0
	245.3	255.4	268.3	344.8	257.0	352.9	437.8	421.2	428.0	442.9
117.0	324.0	204.7	214.7	207.3	219.8	231.7	220.0	235.4	311.5	246.3
	247.4	255.8	269.7	344.8	258.8	353.1	438.0	421.2	428.2	443.1
119.0	348.0	207.7	217.0	210.3	222.6	234.4	222.9	238.5	311.1	248.4
	250.3	257.6	270.9	344.8	260.3	353.3	438.2	421.2	428.4	443.3
121.0	371.8	209.9	218.7	212.5	224.7	236.5	225.1	241.0	310.8	250.8
	253.4	260.0	271.7	344.8	261.5	353.4	438.3	421.1	428.5	443.4
123.0	394.9	211.5	220.0	214.1	226.3	238.1	226.7	242.8	310.5	253.1
	256.4	262.5	272.3	344.8	262.3	353.5	438.4	421.0	428.6	443.4
125.0	417.1	212.4	220.8	215.1	227.3	239.1	227.6	243.9	310.3	255.0
	258.8	264.8	272.6	344.9	262.8	353.6	438.5	420.9	428.7	443.5
127.0	438.5	212.9	221.3	215.6	227.9	239.8	228.2	244.6	310.1	256.6
	260.9	266.9	272.8	344.9	263.0	353.6	438.5	420.8	428.8	443.5
129.0	459.2	213.0	221.4	215.7	228.1	240.1	228.3	244.8	310.0	257.8
	262.5	268.6	272.8	344.8	263.1	353.6	438.5	420.8	428.8	443.6
131.0	478.8	212.9	221.3	215.6	228.0	240.2	228.2	244.8	309.9	258.6
	263.7	269.9	272.8	344.8	263.0	353.6	438.5	420.7	428.8	443.6
133.0	497.9	212.6	221.3	215.4	227.9	240.3	228.0	244.7	309.8	259.4
	264.7	271.1	272.7	344.8	262.9	353.6	438.5	420.6	428.8	443.6
135.0	516.3	212.1	220.9	214.9	227.5	240.0	227.6	244.2	309.7	259.8
	265.4	271.9	272.5	344.8	262.6	353.6	438.5	420.5	428.8	443.6
137.0	534.0	211.5	220.6	214.3	227.0	239.8	227.0	243.7	309.7	260.0
	265.9	272.5	272.3	344.8	262.3	353.6	438.5	420.4	428.8	443.6
139.0	551.1	210.8	220.1	213.6	226.5	239.4	226.4	243.1	309.6	260.0
	266.1	272.9	272.1	344.7	261.9	353.6	438.5	420.3	428.7	443.6
141.0	567.5	209.9	219.6	212.8	225.8	238.9	225.5	242.4	309.6	259.8
	266.1	273.0	271.7	344.7	261.4	353.6	438.5	420.2	428.7	443.6
143.0	583.3	209.1	218.9	211.9	225.0	238.3	224.8	241.5	309.6	259.7
	266.2	273.2	271.4	344.7	261.0	353.6	438.5	420.1	428.7	443.6
145.0	598.6	208.1	218.4	211.0	224.4	237.8	223.8	240.7	309.5	259.3
	265.9	273.0	271.1	344.7	260.4	353.6	438.5	420.1	428.6	443.5
147.0	613.2	207.2	217.8	210.0	223.6	237.2	223.0	239.9	309.5	259.0
	265.7	273.0	270.7	344.6	259.9	353.6	438.4	420.0	428.6	443.5
149.0	627.3	206.2	217.1	209.2	222.8	236.6	222.1	239.0	309.5	258.5
	265.4	272.7	270.3	344.6	259.4	353.6	438.4	419.9	428.6	443.5
155.0	655.3	203.7	215.5	206.7	221.0	235.0	219.8	236.9	309.4	257.2
	264.4	272.0	269.4	344.5	258.0	353.5	438.4	419.8	428.5	443.5
165.0	721.9	198.7	212.2	201.6	217.2	231.6	215.2	232.7	309.4	253.8
	261.3	269.3	267.4	344.4	255.1	353.5	438.3	419.5	428.3	443.4
175.0	768.8	194.0	209.3	197.1	214.1	228.6	210.8	229.2	309.3	250.0
	257.8	265.9	265.4	344.3	252.6	353.4	438.2	419.3	428.2	443.4
185.0	807.7	189.7	206.4	193.3	211.4	225.9	206.5	226.0	309.2	246.1
	254.0	262.3	263.6	344.2	249.7	353.4	438.1	419.2	428.1	443.3
195.0	839.9	186.0	204.4	188.8	208.9	223.2	202.0	223.3	309.2	241.8
	249.7	258.0	262.0	344.2	247.2	353.4	438.0	419.0	428.0	443.3

205.0	865.7	182.9	201.5	184.6	205.6	220.0	197.4	220.1	309.2	237.0
	244.9	253.2	260.6	344.1	243.2	353.3	438.0	418.9	427.9	443.2
215.0	887.9	180.2	199.1	179.0	202.9	217.1	192.6	217.4	309.2	232.0
	239.8	248.2	259.3	344.0	239.0	353.3	437.9	418.8	427.8	443.2
225.0	903.2	177.8	197.0	175.5	201.1	215.1	189.3	215.4	309.2	228.5
	236.3	244.6	258.3	343.9	235.1	353.2	437.9	418.8	427.8	443.2
235.0	911.6	175.4	195.6	171.3	199.4	213.3	185.8	213.7	309.1	224.7
	232.4	240.7	256.7	344.0	229.9	353.2	437.9	418.7	427.7	443.2
245.0	924.6	173.1	194.5	167.8	198.5	212.2	182.9	212.7	309.1	221.6
	229.2	237.5	255.4	343.9	227.1	353.2	437.8	418.7	427.7	443.2
255.0	942.2	172.3	194.0	165.1	197.8	211.4	180.6	212.0	309.2	219.1
	226.7	235.0	254.7	344.0	225.3	353.2	437.8	418.7	427.7	443.2
265.0	954.1	169.5	193.2	161.8	196.9	210.5	177.9	211.1	309.2	216.3
	223.8	232.1	252.0	343.8	222.9	353.2	437.8	418.6	427.7	443.2
275.0	960.4	167.7	192.7	158.8	196.5	209.8	175.5	210.5	309.0	213.6
	221.1	229.2	249.5	343.7	220.9	353.1	437.8	418.6	427.7	443.1
285.0	966.6	166.8	192.4	157.5	196.1	209.5	174.0	210.1	308.9	211.9
	219.4	227.6	248.2	343.6	219.9	353.1	437.8	418.6	427.7	443.1
295.0	972.9	164.1	191.9	154.6	195.7	208.9	171.7	209.7	308.9	209.3
	216.8	224.9	247.1	343.6	217.8	353.0	437.8	418.6	427.6	443.1

O3 RADIATIVE PROPERTIES

STATE	ENERGY(CM-1)	DEGENERACY
O3(000)	.000	1.
O3(010)	700.931	1.
O3(001)	1042.084	1.
O3(100)	1103.140	1.
O3(020)	1399.275	1.
O3(011)	1726.528	1.
O3(110)	1796.261	1.
O3(002)	2057.892	1.
O3(101)	2110.785	1.
O3(200)	2201.157	1.
O3(111)	2785.245	1.
O3(003)	3041.200	1.
O3(004)	3988.000	1.
O3(005)	4910.000	1.
O3(006)	5803.000	1.
O3(007)	6665.000	1.
O3(008)	7497.000	1.
O3(009)	8299.000	1.

TRANSITION		FREQUENCY(CM-1)	ESHINE T(K)	RADIANCE
O3(010)	-O3(000)	700.931	230.0	Y
O3(001)	-O3(000)	1042.084	260.0	Y
O3(100)	-O3(000)	1103.140	285.0	Y
O3(011)	-O3(000)	1726.528	240.0	Y
O3(110)	-O3(000)	1796.261	250.0	Y
O3(002)	-O3(000)	2057.892	280.0	Y
O3(101)	-O3(000)	2110.785	230.0	Y
O3(200)	-O3(000)	2201.157	270.0	Y
O3(111)	-O3(000)	2785.245	285.0	Y
O3(003)	-O3(000)	3041.200	280.0	Y
O3(020)	-O3(010)	698.344	230.0	Y
O3(011)	-O3(010)	1025.597	260.0	Y
O3(110)	-O3(010)	1095.330	285.0	Y
O3(111)	-O3(010)	2084.314	280.0	Y
O3(002)	-O3(001)	1015.808	250.0	Y
O3(101)	-O3(100)	1007.645	250.0	Y
O3(003)	-O3(002)	983.308	285.0	Y
O3(004)	-O3(003)	946.800	285.0	Y
O3(005)	-O3(004)	922.000	285.0	Y
O3(006)	-O3(005)	893.000	285.0	Y
O3(007)	-O3(006)	862.000	285.0	Y
O3(008)	-O3(007)	832.000	285.0	Y
O3(009)	-O3(008)	802.000	285.0	Y

EXCITED STATE NUMBER DENSITIES(MOLEC/CM3)

ALT(KM)	O3(000)	O3(010)	O3(001)	O3(100)	O3(020)	O3(011)	O3(110)	O3(002)	O3(101)	O3(200)
	O3(111)	O3(003)	O3(004)	O3(005)	O3(006)	O3(007)	O3(008)	O3(009)		
61.0	.575E+10	.927E+08	.125E+08	.870E+07	.152E+07	.220E+06	.147E+06	.648E+05	.471E+05	.275E+05
	.549E+03	.355E+05	.175E+05	.842E+04	.370E+04	.139E+04	.372E+03	.678E+02		
63.0	.334E+10	.490E+08	.632E+07	.438E+07	.729E+06	.102E+06	.670E+05	.449E+05	.323E+05	.186E+05
	.272E+03	.319E+05	.157E+05	.759E+04	.333E+04	.125E+04	.335E+03	.610E+02		
65.0	.172E+10	.230E+08	.285E+07	.196E+07	.309E+06	.416E+05	.270E+05	.337E+05	.240E+05	.137E+05
	.141E+03	.285E+05	.141E+05	.680E+04	.299E+04	.112E+04	.301E+03	.546E+02		
67.0	.798E+09	.966E+07	.117E+07	.792E+06	.117E+06	.153E+05	.977E+04	.274E+05	.193E+05	.108E+05
	.821E+02	.252E+05	.125E+05	.605E+04	.266E+04	.998E+03	.268E+03	.486E+02		
69.0	.355E+09	.391E+07	.470E+06	.317E+06	.426E+05	.551E+04	.342E+04	.233E+05	.163E+05	.898E+04
	.544E+02	.221E+05	.110E+05	.533E+04	.235E+04	.881E+03	.237E+03	.429E+02		
71.0	.143E+09	.147E+07	.189E+06	.126E+06	.143E+05	.191E+04	.115E+04	.213E+05	.148E+05	.805E+04
	.407E+02	.204E+05	.102E+05	.494E+04	.218E+04	.820E+03	.220E+03	.400E+02		
73.0	.671E+08	.674E+06	.101E+06	.667E+05	.592E+04	.864E+03	.505E+03	.204E+05	.140E+05	.752E+04
	.333E+02	.192E+05	.970E+04	.471E+04	.208E+04	.784E+03	.211E+03	.384E+02		
75.0	.359E+08	.372E+06	.674E+05	.441E+05	.299E+04	.491E+03	.280E+03	.189E+05	.129E+05	.686E+04
	.270E+02	.176E+05	.894E+04	.435E+04	.193E+04	.729E+03	.197E+03	.359E+02		
77.0	.226E+08	.245E+06	.522E+05	.339E+05	.180E+04	.331E+03	.184E+03	.173E+05	.117E+05	.614E+04
	.214E+02	.157E+05	.806E+04	.394E+04	.175E+04	.665E+03	.180E+03	.329E+02		
79.0	.182E+08	.195E+06	.451E+05	.290E+05	.130E+04	.262E+03	.13[illegible]E+03	.154E+05	.104E+05	.536E+04
	.164E+02	.136E+05	.709E+04	.348E+04	.155E+04	.593E+03	.161E+03	.296E+02		
81.0	.197E+08	.186E+06	.412E+05	.263E+05	.113E+04	.240E+03	.115E+03	.127E+05	.845E+04	.432E+04
	.116E+02	.109E+05	.573E+04	.283E+04	.127E+04	.487E+03	.133E+03	.246E+02		
83.0	.297E+08	.227E+06	.435E+05	.275E+05	.125E+04	.281E+03	.114E+03	.967E+04	.639E+04	.322E+04
	.800E+01	.800E+04	.429E+04	.213E+04	.961E+03	.371E+03	.102E+03	.190E+02		
85.0	.411E+08	.275E+06	.490E+05	.307E+05	.137E+04	.348E+03	.120E+03	.714E+04	.467E+04	.232E+04
	.594E+01	.568E+04	.309E+04	.154E+04	.702E+03	.273E+03	.757E+02	.142E+02		
87.0	.446E+08	.292E+06	.539E+05	.335E+05	.139E+04	.398E+03	.128E+03	.621E+04	.403E+04	.199E+04
	.534E+01	.478E+04	.265E+04	.133E+04	.610E+03	.239E+03	.669E+02	.126E+02		
89.0	.411E+08	.277E+06	.534E+05	.333E+05	.133E+04	.411E+03	.133E+03	.552E+04	.357E+04	.176E+04
	.482E+01	.414E+04	.234E+04	.119E+04	.551E+03	.218E+03	.616E+02	.118E+02		
91.0	.327E+08	.225E+06	.446E+05	.278E+05	.110E+04	.357E+03	.119E+03	.420E+04	.270E+04	.133E+04
	.376E+01	.308E+04	.178E+04	.917E+03	.430E+03	.172E+03	.490E+02	.943E+01		
93.0	.238E+08	.166E+06	.330E+05	.206E+05	.833E+03	.278E+03	.989E+02	.271E+04	.172E+04	.851E+03
	.267E+01	.195E+04	.115E+04	.597E+03	.283E+03	.114E+03	.328E+02	.637E+01		
95.0	.168E+08	.119E+06	.233E+05	.146E+05	.626E+03	.207E+03	.816E+02	.152E+04	.957E+03	.474E+03
	.184E+01	.107E+04	.637E+03	.335E+03	.160E+03	.649E+02	.187E+02	.367E+01		
97.0	.114E+08	.819E+05	.158E+05	.992E+04	.460E+03	.148E+03	.664E+02	.774E+03	.482E+03	.240E+03
	.124E+01	.533E+03	.319E+03	.169E+03	.807E+02	.329E+02	.955E+01	.188E+01		
99.0	.693E+07	.514E+05	.976E+04	.619E+04	.310E+03	.951E+02	.497E+02	.372E+03	.228E+03	.114E+03
	.769E+00	.250E+03	.150E+03	.792E+02	.380E+02	.155E+02	.452E+01	.851E+00		
101.0	.420E+07	.322E+05	.605E+04	.387E+04	.210E+03	.607E+02	.373E+02	.173E+03	.104E+03	.527E+02
	.476E+00	.112E+03	.673E+02	.356E+02	.170E+02	.698E+01	.203E+01	.401E+00		
103.0	.294E+07	.233E+05	.433E+04	.280E+04	.163E+03	.445E+02	.320E+02	.795E+02	.470E+02	.241E+02
	.339E+00	.487E+02	.291E+02	.153E+02	.734E+01	.300E+01	.874E+00	.173E+00		
105.0	.206E+07	.169E+05	.314E+04	.207E+04	.127E+03	.326E+02	.272E+02	.366E+02	.214E+02	.112E+02
	.243E+00	.204E+02	.121E+02	.636E+01	.304E+01	.124E+01	.361E+00	.713E-01		
107.0	.145E+07	.124E+05	.232E+04	.155E+04	.989E+02	.240E+02	.229E+02	.171E+02	.102E+02	.546E+01
	.174E+00	.828E+01	.484E+01	.254E+01	.121E+01	.493E+00	.14[illegible]E+00	.283E-01		

109.0	.102E+07	.911E+04	.174E+04	.119E+04	.783E+02	.178E+02	.194E+02	.831E+01	.531E+01	.292E+01
	.125E+00	.318E+01	.181E+01	.946E+00	.450E+00	.183E+00	.532E-01	.105E-01		
111.0	.665E+06	.633E+04	.125E+04	.885E+03	.592E+02	.124E+02	.154E+02	.418E+01	298E+01	.170E+01
	.842E-01	.114E+01	.625E+00	.324E+00	.154E+00	.625E-01	.181E-01	.357E-02		
113.0	.398E+06	.400E+04	.838E+03	.608E+03	.430E+02	.789E+01	.110E+02	.222E+01	.174E+01	.104E+01
	.518E-01	.419E+00	.215E+00	.111E+00	.527E-01	.214E-01	.619E-02	.122E-02		
115.0	.249E+06	.258E+04	.579E+03	.430E+03	.268E+02	.512E+01	.777E+01	.133E+01	.112E+01	.685E+00
	.329E-01	.173E+00	.815E-01	.420E-01	.198E-01	.802E-02	.232E-02	.456E-03		
117.0	.162E+06	.170E+04	.411E+03	.310E+03	.180E+02	.339E+01	.550E+01	.860E+00	767E+00	.476E+00
	.216E-01	.800E-01	.335E-01	.172E-01	.810E-02	.327E-02	.947E-03	.186E-03		
119.0	.108E+06	.114E+04	.296E+03	.226E+03	.122E+02	.228E+01	390E+01	.587E+00	.541E+00	.339E+00
	.145E-01	.407E-01	.147E-01	.752E-02	.354E-02	.143E-02	.413E-03	.810E-04		
121.0	.747E+05	.785E+03	.217E+03	.167E+03	.834E+01	.157E+01	.277E+01	.414E+00	.390E+00	.245E+00
	.100E-01	.226E-01	.686E-02	.349E-02	.164E-02	.662E-03	.191E-03	.375E-04		
123.0	.528E+05	.549E+03	.161E+03	.124E+03	.577E+01	.110E+01	.199E+01	.300E+00	.286E+00	.179E+00
	.705E-02	.136E-01	.339E-02	.172E-02	.808E-03	.326E-03	.941E-04	.184E-04		
125.0	.382E+05	.391E+03	.121E+03	.931E+02	.405E+01	.783E+00	.143E+01	.221E+00	212E+00	.132E+00
	.506E-02	.865E-02	.176E-02	.889E-03	.417E-03	.168E-03	.485E-04	.951E-05		
127.0	.281E+05	.283E+03	.912E+02	.702E+02	.288E+01	.566E+00	.104E+01	.166E+00	.159E+00	.975E-01
	.370E-02	.582E-02	.960E-03	.481E-03	.225E-03	.908E-04	.262E-04	.513E-05		
129.0	.210E+05	.207E+03	.694E+02	.532E+02	.207E+01	.416E+00	.764E+00	.125E+00	.121E+00	.724E-01
	.275E-02	.407E-02	.542E-03	.270E-03	.126E-03	.509E-04	.147E-04	.287E-05		
131.0	.160E+05	.154E+03	.533E+02	.406E+02	.151E+01	.309E+00	.566E+00	.958E-01	922E-01	.540E-01
	.207E-02	.294E-02	.318E-03	.157E-03	.735E-04	.296E-04	.853E-05	.167E-05		
133.0	.123E+05	.117E+03	.414E+02	.312E+02	.112E+01	.233E+00	.424E+00	.740E-01	.711E-01	.406E-01
	.158E-02	.217E-02	.193E-03	.942E-04	.441E-04	.177E-04	.511E-05	.100E-05		
135.0	.956E+04	.890E+02	.322E+02	.241E+02	.839E+00	.173E+00	.320E+00	.575E-01	.552E-01	.306E-01
	.122E-02	.164E-02	.120E-03	.578E-04	.271E-04	.109E-04	.314E-05	.615E-06		
137.0	.752E+04	.687E+02	.254E+02	.188E+02	.636E+00	.137E+00	.244E+00	.452E-01	.433E-01	.232E-01
	.952E-03	126E-02	.767E-04	.364E-04	.170E-04	.685E-05	.197E-05	.387E-06		
139.0	.596E+04	.535E+02	.200E+02	.146E+02	.487E+00	.107E+00	.188E+00	.357E-01	.341E-01	.176E-01
	.750E-03	982E-03	.500E-04	.234E-04	.109E-04	.439E-05	.127E-05	.248E-06		
141.0	.477E+04	421E+02	.159E+02	.115E+02	.377E+00	.839E-01	.146E+00	.283E-01	.270E-01	.135E-01
	.596E-03	.774E-03	.333E-04	.153E-04	.714E-05	.287E-05	.828E-06	.162E-06		
143.0	.384E+04	.334E+02	.128E+02	.909E+01	.294E+00	.665E-01	.114E+00	.227E-01	.216E-01	.104E-01
	.477E-03	.616E-03	.227E-04	.102E-04	.476E-05	.191E-05	.551E-06	108E-06		
145.0	.312E+04	.267E+02	.102E+02	.721E+01	.232E+00	.531E-01	.901E-01	.182E-01	.173E-01	.805E-02
	.385E-03	.495E-03	.157E-04	.688E-05	.321E-05	.129E-05	.372E-06	.728E-07		
147.0	.255E+04	.215E+02	.829E+01	.576E+01	.184E+00	.427E-01	.717E-01	.147E-01	.140E-01	.627E-02
	.312E-03	.401E-03	.110E-04	.472E-05	.220E-05	.885E-06	.255E-06	.499E-07		
149.0	.209E+04	.174E+02	.674E+01	.462E+01	.147E+00	.346E-01	.574E-01	.120E-01	114E-01	.491E-02
	.255E-03	327E-03	789E-05	.328E-05	.153E-05	.614E-06	177E-06	.346E-07		
155.0	.133E+04	107E+02	.415E+01	.276E+01	882E-01	213E-01	345E-01	739E-02	.701E-02	.277E-02
	.160E-03	204E-03	354E-05	.133E-05	621E-06	249E-06	718E-07	141E-07		
165.0	552E+03	428E+01	162E+01	103E+01	.336E-01	844E-02	131E-01	289E-02	277E-02	939E-03
	656E-04	.836E-04	.931E-06	279E-06	130E-06	521E-07	.150E-07	.293E-08		
175.0	249E+03	187E+01	680E+00	422E+00	143E-01	.369E-02	558E-02	122E-02	120E-02	361E-03
	.293E-04	.373E-04	308E-06	.696E-07	321E-07	129E-07	371E-08	726E-09		
185.0	119E+03	878E+00	306E+00	188E+00	654E-02	173E-02	256E-02	554E-03	560E-03	154E-03
	139E-04	.177E-04	120E-06	197E-07	900E-08	361E-08	104E-08	203E-0[illegible]		
195.0	598E+02	433E+00	144E+00	894E-01	317E-02	849E-03	125E-02	262E-03	[illegible]	705E-04
	693E-05	.882E-05	526E-07	613E-08	276E-08	111E-08	319E-09	625E-10		

205.0	.309E+02	.222E+00	.700E-01	.445E-01	.161E-02	.435E-03	.633E-03	.128E-03	.140E-03	.345E-04
	.358E-05	.454E-05	.250E-07	.207E-08	.916E-09	.368E-09	.106E-09	.207E-10		
215.0	.164E+02	.117E+00	.354E-01	.230E-01	.841E-03	.229E-03	.331E-03	.653E-04	.736E-04	.175E-04
	.189E-05	.240E-05	.125E-07	.743E-09	.320E-09	.128E-09	.369E-10	.722E-11		
225.0	.893E+01	.630E-01	.183E-01	.122E-01	.451E-03	.123E-03	.178E-03	.340E-04	.397E-04	.922E-05
	.103E-05	.130E-05	.653E-08	.281E-09	.116E-09	.466E-10	.134E-10	.263E-11		
235.0	.495E+01	.348E-01	.980E-02	.669E-02	.247E-03	.681E-04	.978E-04	.183E-04	.219E-04	.498E-05
	.568E-06	.717E-06	.353E-08	.113E-09	.444E-10	.178E-10	.512E-11	.100E-11		
245.0	.275E+01	.193E-01	.530E-02	.368E-02	.137E-03	.377E-04	.542E-04	.992E-05	.121E-04	.273E-05
	.316E-06	.398E-06	.193E-08	.462E-10	.171E-10	.683E-11	.196E-11	.384E-12		
255.0	.154E+01	.108E-01	.290E-02	.204E-02	.760E-04	.210E-04	.302E-04	.544E-05	.676E-05	.150E-05
	.176E-06	.222E-06	.106E-08	.195E-10	.659E-11	.263E-11	.759E-12	.148E-12		
265.0	.874E+00	.609E-02	.161E-02	.115E-02	.430E-04	.119E-04	.171E-04	.304E-05	.383E-05	.845E-06
	.100E-06	.126E-06	.599E-09	.869E-11	.264E-11	.105E-11	.301E-12	.592E-13		
275.0	.504E+00	.351E-02	.912E-03	.663E-03	.247E-04	.686E-05	.982E-05	.172E-05	.221E-05	.483E-06
	.577E-07	.726E-07	.343E-09	.409E-11	.108E-11	.427E-12	.125E-12	.243E-13		
285.0	.292E+00	.203E-02	.521E-03	.383E-03	.143E-04	.397E-05	.568E-05	.987E-06	.128E-05	.278E-06
	.334E-07	.420E-07	.198E-09	.199E-11	.452E-12	.175E-12	.499E-13	.955E-14		
295.0	.170E+00	.118E-02	.300E-03	.222E-03	.830E-05	.231E-05	.330E-05	.569E-06	.743E-06	.161E-06
	.195E-07	.245E-07	.115E-09	.994E-12	.196E-12	.734E-13	.209E-13	.400E-14		

VIBRATIONAL TEMPERATURES(K)

ALT(KM)	KINETIC	O3(010)	O3(001)	O3(100)	O3(020)	O3(011)	O3(110)	O3(002)	O3(101)	O3(200)
	O3(111)	O3(003)	O3(004)	O3(005)	O3(006)	O3(007)	O3(008)	O3(009)		
61.0	244.3	244.3	244.4	244.4	244.3	244.2	244.4	259.9	255.3	258.5
	247.9	364.8	451.6	525.9	585.6	629.3	651.6	654.0		
63.0	238.8	238.9	239.2	239.1	238.8	238.9	238.9	264.0	263.0	261.8
	245.5	378.5	467.8	543.7	604.3	648.0	669.4	670.1		
65.0	233.3	233.6	234.1	234.1	233.4	233.7	233.6	273.1	271.7	269.6
	245.6	397.4	489.9	567.8	629.4	673.2	693.2	691.5		
67.0	227.8	228.4	229.6	229.5	228.1	228.7	228.5	288.0	285.7	282.5
	249.1	422.2	518.7	599.2	662.0	705.5	723.6	718.7		
69.0	222.3	223.7	226.3	226.0	223.0	224.3	223.8	307.4	304.0	299.2
	255.4	451.8	552.8	636.0	700.0	743.0	758.5	749.6		
71.0	216.9	220.2	226.2	225.6	218.5	221.3	220.3	336.1	330.9	323.6
	265.9	494.0	600.9	687.6	752.7	794.5	806.0	791.3		
73.0	212.3	219.2	230.7	229.6	215.7	220.6	219.1	365.6	358.4	348.2
	276.1	536.4	649.0	738.6	804.3	844.4	851.5	830.7		
75.0	208.4	220.6	238.8	236.8	214.3	221.8	219.7	392.2	383.0	369.8
	284.2	574.0	691.4	783.2	849.1	887.4	890.4	864.1		
77.0	204.5	222.8	247.0	244.1	213.3	223.2	220.5	412.6	401.4	385.7
	289.0	601.6	722.8	816.2	882.1	919.1	918.9	888.5		
79.0	200.6	222.5	249.9	246.5	211.0	222.9	219.3	418.6	406.6	389.6
	288.0	608.0	731.0	825.1	891.4	928.3	927.4	896.0		
81.0	196.7	216.4	243.0	239.8	206.1	219.5	214.4	402.9	391.7	375.9
	279.4	583.2	704.7	798.3	865.3	904.1	906.3	878.5		
83.0	192.7	207.1	229.8	227.2	199.8	214.8	207.2	368.8	359.7	346.9
	264.9	532.4	649.0	740.2	807.7	849.4	857.6	837.3		
85.0	188.8	201.4	222.7	220.4	195.2	212.7	202.7	342.0	334.4	323.8
	254.4	492.4	604.3	693.2	760.5	804.3	816.9	802.4		
87.0	186.9	200.5	223.2	220.7	194.0	213.7	202.5	333.5	326.2	316.1
	251.4	478.6	589.6	677.9	745.5	790.1	804.3	792.0		
89.0	186.9	201.7	225.6	222.9	194.8	215.8	204.4	332.1	324.8	314.9
	251.1	475.4	587.0	676.0	744.2	789.5	804.3	792.5		
91.0	186.9	202.5	227.3	224.5	195.5	217.5	206.4	330.5	323.0	313.3
	250.8	472.0	584.4	574.0	742.8	788.9	804.3	793.0		
93.0	187.4	203.0	227.9	225.1	196.2	218.7	208.6	326.1	318.6	309.3
	250.4	465.1	577.2	667.0	736.3	783.1	799.4	789.1		
95.0	188.5	203.5	227.7	225.1	197.4	219.8	211.2	317.9	310.7	302.2
	250.0	452.8	563.5	652.6	721.9	769.2	786.9	778.4		
97.0	190.5	204.4	227.8	225.3	199.0	220.8	214.4	308.5	301.6	294.1
	250.0	438.9	547.4	635.2	704.1	751.9	770.9	764.5		
99.0	193.4	205.6	228.4	226.1	201.0	221.9	218.2	301.1	294.2	287.6
	250.2	427.7	534.2	620.8	689.2	737.2	757.3	752.5		
101.0	197.3	207.1	[illegible]	227.1	203.2	222.9	222.2	293.2	286.3	280.6
	250.5	415.5	519.6	604.8	672.5	720.5	741.7	738.6		
103.0	202.4	208.5	229.9	228.2	205.4	223.8	226.1	281.5	275.0	270.4
	250.8	397.4	497.9	580.7	647.2	695.1	717.7	717.1		
105.0	209.1	210.0	231.1	229.8	207.6	224.7	230.0	270.6	264.7	261.2
	251.1	379.7	476.3	556.7	621.8	669.5	693.3	695.0		
107.0	218.1	211.7	232.8	232.0	209.9	225.6	233.8	260.9	256.0	253.6
	251.5	362.4	455.0	532.9	596.5	643.8	668.7	672.6		

109.0	231.6	213.8	235.3	235.1	212.5	226.7	237.7	252.7	249.7	248.2
	251.9	345.2	433.5	508.6	570.6	617.4	643.3	649.2		
111.0	252.0	216.7	239.0	239.7	215.9	228.1	242.2	247.2	246.6	246.0
	252.3	329.6	413.4	486.1	546.4	592.6	619.2	627.0		
113.0	276.0	219.2	243.3	244.8	218.7	229.4	246.2	244.8	246.1	246.3
	252.7	317.9	397.6	468.2	527.2	572.8	599.9	609.0		
115.0	300.0	220.7	247.2	249.4	220.3	230.1	249.1	243.8	246.7	247.3
	253.0	308.6	384.2	453.0	510.8	555.9	583.3	593.5		
117.0	324.0	221.4	250.9	253.6	221.2	230.6	251.2	243.8	247.7	248.6
	253.1	301.4	372.8	439.9	496.7	541.3	569.0	580.1		
119.0	348.0	221.6	254.0	257.1	221.4	230.7	252.5	244.1	248.8	249.8
	253.2	295.7	362.9	428.6	484.4	528.5	556.4	568.2		
121.0	371.8	221.4	256.7	260.0	221.2	230.6	253.3	244.6	249.7	250.8
	253.2	291.5	354.1	418.5	473.5	517.2	545.2	557.7		
123.0	394.9	220.8	258.8	262.3	220.7	230.4	253.7	245.2	250.4	251.5
	253.2	288.3	346.5	409.8	464.0	507.3	535.4	548.4		
125.0	417.1	220.1	260.4	263.8	220.0	230.1	253.6	245.6	251.0	251.8
	253.1	286.0	339.7	402.0	455.5	498.4	526.6	540.0		
127.0	438.5	219.2	261.6	264.9	219.1	229.7	253.3	245.9	251.4	251.9
	252.9	284.3	333.7	395.0	447.9	490.5	518.8	532.5		
129.0	459.2	218.3	262.4	265.4	218.2	229.3	252.8	246.1	251.6	251.8
	252.8	283.0	328.4	388.7	441.1	483.3	511.6	525.7		
131.0	478.8	217.[illegible]	262.9	265.6	217.3	228.9	252.2	246.2	251.8	251.4
	252.7	282.1	323.6	383.1	434.9	476.9	505.2	519.6		
133.0	497.9	216.5	263.3	265.6	216.4	228.5	251.5	246.3	251.8	250.9
	252.6	281.4	319.3	378.0	429.3	471.1	499.4	514.0		
135.0	516.3	215.6	263.4	265.3	215.5	228.1	250.8	246.3	251.8	250.3
	252.4	280.9	315.4	373.3	424.2	465.7	494.0	508.8		
137.0	534.0	214.8	263.5	264.8	214.7	227.7	250.1	246.3	251.7	249.6
	252.3	280.5	311.8	369.0	419.4	460.7	489.0	504.0		
139.0	551.1	214.0	263.2	264.1	213.9	227.3	249.3	246.2	251.6	248.8
	252.2	280.1	308.5	364.9	415.0	456.0	484.3	499.5		
141.0	567.5	213.2	263.0	263.3	213.1	226.9	248.6	246.0	251.4	247.9
	252.1	279.9	305.6	361.2	410.9	451.7	479.9	495.3		
143.0	583.3	212.5	262.7	262.5	212.4	226.6	247.9	245.9	251.2	247.0
	252.0	279.7	302.8	357.7	407.1	447.7	475.9	491.4		
145.0	598.6	211.8	262.2	261.5	211.8	226.2	247.3	245.7	251.0	246.1
	251.9	279.5	300.3	354.4	403.5	443.9	472.1	487.8		
147.0	613.2	211.2	261.8	260.6	211.1	225.9	246.7	245.[illegible]	[illegible].8	245.2
	251.8	279.3	298.0	351.4	400.1	440.3	468.5	[illegible]		
149.0	627.3	210.6	261.4	259.6	210.6	225.6	246.1	[illegible]	250.5	244.3
	251.7	279.2	295.9	348.5	396.9	436.9	465.1	481.0		
155.0	665.3	209.4	260.0	257.1	209.3	225.0	244.8	244.8	250.0	242.2
	251.6	279.0	290.7	341.0	388.7	428.2	456.3	472.5		
165.0	721.9	207.5	257.1	252.5	207.4	224.0	242.7	243.5	248.9	238.4
	251.3	278.7	284.0	330.0	376.6	415.4	443.4	459.9		
175.0	768.8	206.2	253.9	248.7	206.1	223.4	241.4	242.2	248.1	235.6
	251.1	278.4	279.7	321.1	366.6	404.9	432.7	449.5		
185.0	807.7	205.3	251.3	246.0	205.2	222.9	240.4	241.1	247.5	233.5
	251.0	278.3	277.0	313.6	358.[illegible]	395.9	423.6	440.6		
195.0	839.9	204.6	248.8	244.0	204.5	222.6	239.8	240.0	247.1	232.1
	250.9	278.2	275.2	307.2	350.9	388.1	415.6	432.8		

205.0	865.7	204.2	246.1	242.5	204.1	222.3	239.3	238.9	246.8	231.0
	250.9	278.1	274.0	301.5	344.4	381.2	408.6	425.9		
215.0	887.9	203.9	244.2	241.5	203.7	222.2	239.0	238.1	246.6	230.3
	250.8	278.0	273.3	296.6	338.5	374.9	402.1	419.6		
225.0	903.2	203.6	242.2	240.8	203.5	222.0	238.8	237.3	246.4	229.8
	250.8	277.9	272.8	292.1	333.1	369.1	396.2	413.8		
235.0	911.6	203.4	240.9	240.3	203.3	221.9	238.6	236.7	246.3	229.4
	250.8	277.9	272.4	288.3	328.2	363.9	390.9	408.5		
245.0	924.6	203.3	239.8	239.9	203.2	221.8	238.5	236.2	246.2	229.1
	250.8	277.8	272.2	284.7	323.5	358.9	385.7	403.4		
255.0	942.2	203.2	238.9	239.6	203.0	221.8	238.4	235.9	246.2	228.8
	250.7	277.8	272.0	281.5	319.0	353.9	380.6	398.4		
265.0	954.1	203.1	238.1	239.4	203.0	221.8	238.3	235.6	246.2	228.7
	250.7	277.8	271.9	278.8	314.7	349.4	375.9	393.8		
275.0	960.4	203.0	237.4	239.2	202.9	221.7	238.3	235.3	246.1	228.5
	250.7	277.8	271.8	276.6	310.8	345.0	371.6	389.4		
285.0	966.6	203.0	236.9	239.1	202.8	221.7	238.2	235.0	246.1	228.4
	250.7	277.8	271.8	274.8	307.0	340.8	366.9	384.5		
295.0	972.9	202.9	236.4	239.0	202.8	221.7	238.2	234.8	246.1	228.4
	250.7	277.7	271.7	273.1	303.7	336.8	362.8	380.5		

CO RADIATIVE PROPERTIES

STATE	ENERGY(CM-1)	DEGENERACY
CO(0)	.000	1.
CO(1)	2143.272	1.
CO(2)	4260.063	1.

TRANSITION		FREQUENCY(CM-1)	ESHINE T(K)	RADIANCE
CO(1)	-CO(0)	2143.272	230.0	Y
CO(2)	-CO(0)	4260.063	280.0	Y
CO(2)	-CO(1)	2116.791	280.0	Y

EXCITED STATE NUMBER DENSITIES(MOLEC/CM3)

ALT(KM)	CO(0)	CO(1)	CO(2)
61.0	.954E+09	.817E+04	.492E+02
63.0	.104E+10	.946E+04	.539E+02
65.0	.114E+10	.110E+05	.588E+02
67.0	.121E+10	.125E+05	.625E+02
69.0	.122E+10	.133E+05	.629E+02
71.0	.123E+10	.141E+05	.635E+02
73.0	.125E+10	.149E+05	.647E+02
75.0	.124E+10	.152E+05	.639E+02
77.0	.119E+10	.150E+05	.613E+02
79.0	.116E+10	.148E+05	.598E+02
81.0	.117E+10	.151E+05	.602E+02
83.0	.114E+10	.151E+05	.591E+02
85.0	.112E+10	.149E+05	.580E+02
87.0	.110E+10	.146E+05	.568E+02
89.0	.107E+10	.142E+05	.552E+02
91.0	.106E+10	.141E+05	.547E+02
93.0	.101E+10	.135E+05	.523E+02
95.0	.927E+09	.123E+05	.479E+02
97.0	.829E+09	.110E+05	.428E+02
99.0	.746E+09	.982E+04	.385E+02
101.0	.645E+09	.845E+04	.333E+02
103.0	.522E+09	.679E+04	.270E+02
105.0	.416E+09	.538E+04	.215E+02
107.0	.321E+09	.414E+04	.166E+02
109.0	.238E+09	.306E+04	.123E+02
111.0	.171E+09	.219E+04	.885E+01
113.0	.122E+09	.156E+04	.633E+01
115.0	.900E+08	.115E+04	.465E+01
117.0	.678E+08	.862E+03	.350E+01
119.0	.522E+08	.663E+03	.269E+01
121.0	.409E+08	.519E+03	.211E+01
123.0	.325E+08	.414E+03	.168E+01
125.0	.263E+08	.335E+03	.136E+01
127.0	.216E+08	.275E+03	.111E+01
129.0	.179E+08	.228E+03	.924E+00
131.0	.150E+08	.191E+03	.774E+00
133.0	.126E+08	.162E+03	.655E+00
135.0	.107E+08	.138E+03	.558E+00
137.0	.920E+07	.119E+03	.480E+00
139.0	.794E+07	.103E+03	.416E+00
141.0	.688E+07	.894E+02	.363E+00
143.0	.600E+07	.783E+02	.319E+00
145.0	.525E+07	.688E+02	.282E+00
147.0	.462E+07	.608E+02	.251E+00
149.0	.408E+07	.539E+02	.225E+00
155.0	.300E+07	.403E+02	.174E+00
165.0	.174E+07	.239E+02	.114E+00
175.0	.107E+07	.149E+02	.787E-01
185.0	.682E+06	.959E+01	.558E-01

195.0	.448E+06	.633E+01	.397E-01
205.0	.301E+06	.426E+01	.279E-01
215.0	.206E+06	.290E+01	.196E-01
225.0	.143E+06	.200E+01	.134E-01
235.0	.101E+06	.139E+01	.905E-02
245.0	.715E+05	.976E+00	.626E-02
255.0	.506E+05	.687E+00	.443E-02
265.0	.362E+05	.488E+00	.309E-02
275.0	.262E+05	.350E+00	.213E-02
285.0	.190E+05	.252E+00	.148E-02
295.0	.138E+05	.182E+00	.104E-02

VIBRATIONAL TEMPERATURES(K)

ALT(KM)	KINETIC	CO(1)	CO(2)
61.0	244.3	264.3	365.3
63.0	238.8	265.6	365.3
65.0	233.3	267.0	365.3
67.0	227.8	268.5	365.3
69.0	222.3	269.9	365.3
71.0	216.9	271.1	365.3
73.0	212.3	272.0	365.3
75.0	208.4	272.7	365.3
77.0	204.5	273.5	365.3
79.0	200.6	273.7	365.3
81.0	196.7	274.1	365.3
83.0	192.7	274.4	365.3
85.0	188.8	274.6	365.3
87.0	186.9	274.7	365.3
89.0	186.9	274.7	365.3
91.0	186.9	274.7	365.3
93.0	187.4	274.7	365.3
95.0	188.5	274.6	365.3
97.0	190.5	274.5	365.3
99.0	193.4	274.4	365.3
101.0	197.3	274.3	365.3
103.0	202.4	274.1	365.3
105.0	209.1	274.0	365.3
107.0	218.1	273.9	365.3
109.0	231.6	273.8	365.3
111.0	252.0	273.7	365.3
113.0	276.0	273.6	365.3
115.0	300.0	273.6	365.3
117.0	324.0	273.5	365.3
119.0	348.0	273.5	365.3
121.0	371.8	273.5	365.3
123.0	394.9	273.5	365.3
125.0	417.1	273.6	365.3
127.0	438.5	273.6	365.3
129.0	459.2	273.6	365.3
131.0	478.8	273.7	365.4
133.0	497.9	273.8	365.4
135.0	516.3	273.8	365.4
137.0	534.0	273.9	365.5
139.0	551.1	274.0	365.6
141.0	567.5	274.1	365.8
143.0	583.3	274.2	365.9
145.0	598.6	274.3	366.2
147.0	613.2	274.4	366.4
149.0	627.3	274.5	366.7
155.0	665.3	274.9	367.9
165.0	721.9	275.4	370.5
175.0	768.8	275.8	373.2
185.0	807.7	276.0	375.6

195.0	839.9	276.1	377.4
205.0	865.7	276.1	378.5
215.0	887.9	276.0	379.1
225.0	903.2	275.8	378.7
235.0	911.6	275.5	377.6
245.0	924.6	275.3	377.1
255.0	942.2	275.2	377.2
265.0	954.1	275.0	376.6
275.0	960.4	274.8	375.5
285.0	966.6	274.6	374.6
295.0	972.9	274.4	373.7

NO RADIATIVE PROPERTIES

STATE	ENERGY(CM-1)	DEGENERACY
NO(0)	.000	1.
NO(1)	1876.077	1.
NO(2)	3724.067	1.

TRANSITION		FREQUENCY(CM-1)	ESHINE T(K)	RADIANCE
NO(1)	-NO(0)	1876.077	240.0	Y
NO(2)	-NO(0)	3724.067	230.0	Y
NO(2)	-NO(1)	1847.990	240.0	Y

EXCITED STATE NUMBER DENSITIES(MOLEC/CM3)

ALT(KM)	NO(0)	NO(1)	NO(2)
61.0	.810E+08	.968E+03	.581E+01
63.0	.650E+08	.766E+03	.466E+01
65.0	.520E+08	.606E+03	.372E+01
67.0	.415E+08	.478E+03	.297E+01
69.0	.330E+08	.376E+03	.235E+01
71.0	.260E+08	.293E+03	.185E+01
73.0	.205E+08	.227E+03	.144E+01
75.0	.160E+08	.174E+03	.111E+01
77.0	.127E+08	.136E+03	.877E+00
79.0	.105E+08	.109E+03	.715E+00
81.0	.915E+07	.921E+02	.611E+00
83.0	.845E+07	.832E+02	.558E+00
85.0	.845E+07	.812E+02	.551E+00
87.0	.960E+07	.850E+02	.595E+00
89.0	.122E+08	.935E+02	.687E+00
91.0	.160E+08	.105E+03	.804E+00
93.0	.205E+08	.120E+03	.943E+00
95.0	.265E+08	.146E+03	.116E+01
97.0	.330E+08	.181E+03	.142E+01
99.0	.380E+08	.213E+03	.165E+01
101.0	.410E+08	.243E+03	.182E+01
103.0	.430E+08	.275E+03	.197E+01
105.0	.445E+08	.316E+03	.213E+01
107.0	.445E+08	.366E+03	.223E+01
109.0	.435E+08	.454E+03	.229E+01
111.0	.425E+08	.669E+03	.236E+01
113.0	.410E+08	.110E+04	.240E+01
115.0	.395E+08	.177E+04	.248E+01
117.0	.380E+08	.271E+04	.265E+01
119.0	.365E+08	.391E+04	.307E+01
121.0	.354E+08	.535E+04	.393E+01
123.0	.342E+08	.690E+04	.540E+01
125.0	.330E+08	.842E+04	.759E+01
127.0	.318E+08	.986E+04	.106E+02
129.0	.306E+08	.111E+05	.145E+02
131.0	.293E+08	.122E+05	.190E+02
133.0	.281E+08	.131E+05	.242E+02
135.0	.268E+08	.138E+05	.299E+02
137.0	.257E+08	.143E+05	.359E+02
139.0	.245E+08	.145E+05	.420E+02
141.0	.234E+08	.146E+05	.478E+02
143.0	.222E+08	.145E+05	.533E+02
145.0	.211E+08	.143E+05	.582E+02
147.0	.200E+08	.140E+05	.628E+02
149.0	.190E+08	.136E+05	.667E+02
155.0	.160E+08	.120E+05	.740E+02
165.0	.111E+08	.832E+04	.684E+02
175.0	.728E+07	.509E+04	.51[illegible]E+02
185.0	.471E+07	.299E+04	353E+02

195.0	.301E+07	.170E+04	.225E+02
205.0	.197E+07	.976E+03	.141E+02
215.0	.135E+07	.579E+03	.895E+01
225.0	.917E+06	.336E+03	.543E+01
235.0	.625E+06	.193E+03	.318E+01
245.0	.426E+06	.113E+03	.192E+01
255.0	.295E+06	.683E+02	.122E+01
265.0	.209E+06	.418E+02	.766E+00
275.0	.148E+06	.252E+02	.467E+00
285.0	.105E+06	.153E+02	.286E+00
295.0	.742E+05	.933E+01	.175E+00

VIBRATIONAL TEMPERATURES(K)

ALT(KM)	KINETIC	NO(1)	NO(2)
61.0	244.3	238.1	325.7
63.0	238.8	237.8	325.7
65.0	233.3	237.6	325.7
67.0	227.8	237.4	325.7
69.0	222.3	237.2	325.6
71.0	216.9	236.9	325.5
73.0	212.3	236.6	325.3
75.0	208.4	236.2	325.1
77.0	204.5	235.7	324.9
79.0	200.6	235.1	324.6
81.0	196.7	234.6	324.3
83.0	192.7	234.1	324.1
85.0	188.8	233.7	323.8
87.0	186.9	232.0	322.8
89.0	186.9	229.1	320.9
91.0	186.9	226.2	318.8
93.0	187.4	224.0	317.2
95.0	188.5	222.9	316.2
97.0	190.5	222.8	315.9
99.0	193.4	223.3	316.1
101.0	197.3	224.2	316.5
103.0	202.4	225.7	317.1
105.0	209.1	227.7	317.9
107.0	218.1	230.6	318.8
109.0	231.6	235.3	319.7
111.0	252.0	244.1	320.7
113.0	276.0	256.4	321.8
115.0	300.0	269.6	323.1
117.0	324.0	282.7	325.2
119.0	348.0	295.2	328.9
121.0	371.8	306.8	334.6
123.0	394.9	317.3	342.1
125.0	417.1	326.3	350.6
127.0	438.5	334.2	359.3
129.0	459.2	340.9	367.9
131.0	478.8	346.7	376.0
133.0	497.9	352.0	383.8
135.0	516.3	356.4	390.9
137.0	534.0	360.1	397.5
139.0	551.1	363.3	403.5
141.0	567.5	365.9	409.0
143.0	583.3	368.2	414.1
145.0	598.6	370.0	418.7
147.0	613.2	371.5	422.9
149.0	627.3	372.7	426.6
155.0	665.3	375.4	436.2
165.0	721.9	374.9	446.5
175.0	768.8	371.6	451.9
185.0	807.7	366.7	454.0

195.0	839.9	360.9	453.9
205.0	865.7	354.6	452.1
215.0	887.9	348.3	449.5
225.0	903.2	341.2	445.2
235.0	911.6	333.9	439.6
245.0	924.6	327.7	435.3
255.0	942.2	322.5	432.2
265.0	954.1	317.0	428.1
275.0	960.4	311.1	423.0
285.0	966.6	305.7	418.2
295.0	972.9	300.6	413.6

LINE-OF-SIGHT GEOMETRY INFORMATION

PATH SELECTION:	OBSERVER TO SOURCE
OBSERVER ALTITUDE(KM):	70.00
OBSERVER LONGITUDE(DEG):	62.00
OBSERVER LATITUDE(DEG):	50.00
SOURCE ALTITUDE(KM):	290.00
SOURCE LONGITUDE(DEG):	62.00
SOURCE LATITUDE(DEG):	60.00

SEGMENT	LOWER ALT.(KM)	UPPER ALT.(KM)	SEGMENT LENGTH(KM)	COLUMN DENSITIES(MOLEC/CM2)				
				H2O	CO2	O3	CO	NO
1	70.00	72.00	19.29	.1221E+17	.9173E+18	.2798E+15	.2371E+16	.5017E+14
2	72.00	74.00	18.77	.8464E+16	.6683E+18	.1276E+15	.2352E+16	.3847E+14
3	74.00	76.00	18.28	.5733E+16	.4830E+18	.6672E+14	.2261E+16	.2925E+14
4	76.00	78.00	17.83	.3850E+16	.3477E+18	.4100E+14	.2117E+16	.2273E+14
5	78.00	80.00	17.41	.2533E+16	.2492E+18	.3221E+14	.2014E+16	.1837E+14
6	80.00	82.00	17.02	.1598E+16	.1777E+18	.3404E+14	.1984E+16	.1557E+14
7	82.00	84.00	16.65	.9671E+15	.1261E+18	.4996E+14	.1905E+16	.1407E+14
8	84.00	86.00	16.31	.5745E+15	.8898E+17	.6770E+14	.1831E+16	.1378E+14
9	86.00	88.00	15.99	.3348E+15	.6198E+17	.7196E+14	.1759E+16	.1535E+14
10	88.00	90.00	15.69	.1896E+15	.4261E+17	.6511E+14	.1676E+16	.1922E+14
11	90.00	92.00	15.40	.1055E+15	.2931E+17	.5083E+14	.1631E+16	.2464E+14
12	92.00	94.00	15.13	.5601E+14	.2015E+17	.3632E+14	.1533E+16	.3102E+14
13	94.00	96.00	14.88	.2928E+14	.1384E+17	.2529E+14	.1379E+16	.3942E+14
14	96.00	98.00	14.63	.1379E+14	.9492E+16	.1683E+14	.1212E+16	.4829E+14
15	98.00	100.00	14.40	.5851E+13	.6516E+16	.1008E+14	.1074E+16	.5472E+14
16	100.00	102.00	14.18	.2728E+13	.4480E+16	.6023E+13	.9148E+15	.5813E+14
17	102.00	104.00	13.97	.1572E+13	.3088E+16	.4152E+13	.7290E+15	.6006E+14
18	104.00	106.00	13.77	.9853E+12	.2136E+16	.2871E+13	.5723E+15	.6126E+14
19	106.00	108.00	13.57	.6325E+12	.1481E+16	.1992E+13	.4363E+15	.6040E+14
20	108.00	110.00	13.39	.4165E+12	.1026E+16	.1380E+13	.3191E+15	.5824E+14
21	110.00	112.00	13.21	.2941E+12	.6712E+15	.8902E+12	.2264E+15	.5615E+14
22	112.00	114.00	13.04	.2264E+12	.4113E+15	.5265E+12	.1597E+15	.5347E+14
23	114.00	116.00	12.88	.1781E+12	.2626E+15	.3255E+12	.1160E+15	.5086E+14
24	116.00	118.00	12.72	.1427E+12	.1736E+15	.2089E+12	.8629E+14	.4833E+14
25	118.00	120.00	12.57	.1161E+12	.1182E+15	.1384E+12	.6557E+14	.4587E+14
26	120.00	122.00	12.42	.9576E+11	.8260E+14	.9430E+11	.5075E+14	.4395E+14
27	122.00	124.00	12.28	.8005E+11	.5911E+14	.6589E+11	.3997E+14	.4197E+14
28	124.00	126.00	12.14	.6772E+11	.4320E+14	.4708E+11	.3196E+14	.4005E+14
29	126.00	128.00	12.01	.5789E+11	.3214E+14	.3429E+11	.2590E+14	.3816E+14
30	128.00	130.00	11.88	.4992E+11	.2429E+14	.2539E+11	.2124E+14	.3635E+14
31	130.00	132.00	11.76	.4341E+11	.1862E+14	.1909E+11	.1759E+14	.3451E+14
32	132.00	134.00	11.64	.3801E+11	.1444E+14	.1454E+11	.1470E+14	.3267E+14
33	134.00	136.00	11.53	.3348E+11	.1132E+14	.1119E+11	.1238E+14	.3093E+14
34	136.00	138.00	11.41	.2965E+11	.8964E+13	.8711E+10	.1051E+14	.2929E+14
35	138.00	140.00	11.30	.2640E+11	.7159E+13	.6841E+10	.8970E+13	.2775E+14
36	140.00	142.00	11.20	.2361E+11	.5763E+13	.5419E+10	.7705E+13	.2619E+14
37	142.00	144.00	11.10	.2120E+11	.4673E+13	.4325E+10	.6653E+13	.2464E+14
38	144.00	146.00	10.99	.1912E+11	.3814E+13	.3477E+10	.5773E+13	.2318E+14
39	146.00	148.00	10.90	.1729E+11	.3131E+13	.2813E+10	.5031E+13	.2181E+14
40	148.00	150.00	10.80	.1569E+11	.2586E+13	.2289E+10	.4403E+13	.2052E+14

41	150.00	160.00	52.68	.6120E+11	.8223E+13	.7081E+10	.1580E+14	.8429E+14
42	160.00	170.00	50.65	.4031E+11	.3516E+13	.2831E+10	.8819E+13	.5650E+14
43	170.00	180.00	48.84	.2777E+11	.1627E+13	.1232E+10	.5216E+13	.3556E+14
44	180.00	190.00	47.22	.1977E+11	.7977E+12	.5705E+09	.3218E+13	.2226E+14
45	190.00	200.00	45.76	.1443E+11	.4084E+12	.2766E+09	.2050E+13	.1379E+14
46	200.00	210.00	44.44	.1074E+11	.2164E+12	.1390E+09	.1340E+13	.8779E+13
47	210.00	220.00	43.22	.8118E+10	.1176E+12	.7185E+08	.8920E+12	.5818E+13
48	220.00	230.00	42.11	.6223E+10	.6535E+11	.3799E+08	.6042E+12	.3862E+13
49	230.00	240.00	41.08	.4837E+10	.3707E+11	.2053E+08	.4161E+12	.2567E+13
50	240.00	250.00	40.13	.3760E+10	.2114E+11	.1116E+08	.2871E+12	.1708E+13
51	250.00	260.00	39.25	.2923E+10	.1211E+11	.6104E+07	.1985E+12	.1157E+13
52	260.00	270.00	38.42	.2296E+10	.7050E+10	.3393E+07	.1390E+12	.8020E+12
53	270.00	280.00	37.65	.1823E+10	.4168E+10	.1917E+07	.9851E+11	.5566E+12
54	280.00	290.00	36.93	.1451E+10	.2478E+10	.1090E+07	.7010E+11	.3867E+12

54 LAYERS TOTAL PATH LENGTH: 1162.75

BAND RADIANCE SUMMARY

TRANSITION	FREQUENCY(CM-1)	NO. OF LINES TOTAL	NO. OF LINES RELAYERED	BAND RADIANCE (W/SR/CM2)
H2O(010) -H2O(000)	1594.750	1741	0	.35917E-07
H2O(020) -H2O(000)	3151.630	1132	0	.12333E-09
H2O(100) -H2O(000)	3657.053	1302	0	.86359E-10
H2O(001) -H2O(000)	3755.930	1546	0	.10444E-07
H2O(030) -H2O(000)	4666.793	413	0	.17380E-15
H2O(110) -H2O(000)	5234.977	188	0	.21018E-17
H2O(011) -H2O(000)	5331.269	148	0	.59619E-17
H2O(020) -H2O(010)	1556.880	686	0	.39387E-08
H2O(100) -H2O(010)	2062.303	402	0	.15772E-1[illegible]
H2O(001) -H2O(010)	2161.180	365	0	.20350E-09
H2O(030) -H2O(010)	3072.043	313	0	.32815E-13
H2O(110) -H2O(010)	3640.227	365	0	.87867E-14
H2O(011) -H2O(010)	3736.519	527	0	.34855E-12
H2O(030) -H2O(020)	1515.163	121	0	.57705E-12
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TOTAL		9249	0	.50730E-07
CO2(01101)-CO2(00001)	667.380	153	0	.22564E-05
CO2(11102)-CO2(00001)	1932.470	117	0	.83399E-10
CO2(11101)-CO2(00001)	2076.856	127	0	.36010E-09
CO2(00011)-CO2(00001)	2349.143	110	0	.18782E-07
CO2(10012)-CO2(00001)	3612.842	99	0	.11264E-08
CO2(10011)-CO2(00001)	3714.783	99	0	.67392E-09
CO2(20013)-CO2(00001)	4853.623	83	0	.23191E-10
CO2(20012)-CO2(00001)	4977.834	62	0	.81420E-10
CO2(20011)-CO2(00001)	5099.660	0	0	.00000E+00
CO2(10002)-CO2(01101)	618.029	136	0	.11357E-06
CO2(02201)-CO2(01101)	667.752	276	0	.60175E-06
CO2(10001)-CO2(01101)	720.805	136	0	.96740E-07
CO2(01111)-CO2(01101)	2336.632	278	[illegible]	.19163E-07
CO2(11102)-CO2(10002)	647.061	128	0	.69489E-07
CO2(11101)-CO2(10002)	791.447	110	0	.18706E-08
CO2(00011)-CO2(10002)	1063.734	77	0	.13659E-07
CO2(10012)-CO2(10002)	2327.433	93	0	.38259E-06
CO2(20013)-CO2(10002)	3568.214	81	0	.19476E-08
CO2(20012)-CO2(10002)	3692.425	81	0	.22102E-08
CO2(11102)-CO2(02201)	597.338	229	0	.80415E-08
CO2(03301)-CO2(02201)	668.114	247	0	.50987E-07
CO2(11101)-CO2(02201)	741.724	235	0	.86455E-08
CO2(02211)-CO2(02201)	2324.141	250	0	.57894E-07
CO2(11102)-CO2(10001)	544.285	104	0	.83720E-09
CO2(11101)-CO2(10001)	688.671	125	0	.34292E-07
CO2(00011)-CO2(10001)	960.958	75	0	.11701E-07
CO2(10011)-CO2(10001)	2326.598	91	0	.21125E-06
CO2(20012)-CO2(10001)	3589.649	79	0	.14471E-08
CO2(20011)-CO2(10001)	3711.475	81	0	.31085E-08

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TOTAL			3762	0	.39687E-05
O3(010)	-O3(000)	700.931	6340	0	.24768E-08
O3(001)	-O3(000)	1042.084	6992	0	.27897E-07
O3(100)	-O3(000)	1103.140	6671	0	.56487E-09
O3(011)	-O3(000)	1726.528	1709	0	.41286E-11
O3(110)	-O3(000)	1796.261	2137	0	.96663E-12
O3(002)	-O3(000)	2057.892	2164	0	.26180E-09
O3(101)	-O3(000)	2110.785	2165	0	.23016E-08
O3(200)	-O3(000)	2201.157	1530	0	.28077E-10
O3(111)	-O3(000)	2785.245	1449	0	.28625E-12
O3(003)	-O3(000)	3041.200	1575	0	.86237E-09
O3(020)	-O3(010)	698.344	4591	0	.37332E-10
O3(011)	-O3(010)	1025.597	1544	0	.22034E-09
O3(110)	-O3(010)	1095.330	901	0	.28888E-11
O3(111)	-O3(010)	2084.314	1469	0	.43107E-11
O3(002)	-O3(001)	1015.808	1534	0	.92911E-08
O3(101)	-O3(100)	1007.645	1185	0	.29334E-08
O3(003)	-O3(002)	983.308	3510	0	.10705E-07
O3(004)	-O3(003)	946.800	1518	0	.68536E-08
O3(005)	-O3(004)	922.000	1521	0	.39265E-08
O3(006)	-O3(005)	893.000	1533	0	.19266E-08
O3(007)	-O3(006)	862.000	1528	0	.77422E-09
O3(008)	-O3(007)	832.000	1527	0	.21647E-09
O3(009)	-O3(008)	802.000	1526	0	.40422E-10
			-----	-----	------------
TOTAL			56619	0	.71331E-07
CO(1)	-CO(0)	2143.272	79	0	.23022E-07
CO(2)	-CO(0)	4260.063	64	0	.11131E-10
CO(2)	-CO(1)	2116.791	45	0	.34728E-09
			-----	-----	------------
TOTAL			188	0	.23380E-07
NO(1)	-NO(0)	1876.077	833	0	.16868E-07
NO(2)	-NO(0)	3724.067	832	0	.11095E-10
NO(2)	-NO(1)	1847.990	831	0	.16650E-09
			-----	-----	------------
TOTAL			2496	0	.17046E-07

Output file for second test case.

```
        SSSSSS    HH    HH     AAAAAA     RRRRRR       CCCCCC
      SS         HH    HH    AA    AA    RR    RR     CC
     SS         HH    HH    AA    AA    RR    RR     CC
     SSSSS     HHHHHHHH    AAAAAAAA    RRRRRRR     CC
         SS   HH    HH    AA    AA    RR   RR     CC
        SS   HH    HH    AA    AA    RR     RR   CC
 SSSSSS    HH    HH    AA    AA    RR      RR   CCCCCC
```

STRATEGIC HIGH ALTITUDE RADIANCE CODE

VERSION 1.0

***********   CO   NIGHT WINTER 45-LATITUDE   ***********

Sat Feb 4 12:57:41 1989

SELECTED MOLECULAR RADIATORS AND INPUT FILES NAMES

1 MOLECULAR RADIATORS

SPECIES	AFGL #	LINK FILE	STATE FILE	BAND FILE
CO	5	COLINK.DAT	COSTAT.DAT	COBAND.DAT

ATMOSPHERIC PROFILE

ATMOSPHERE FILE NAME: SAT45WN.DAT
NUMBER OF LAYERS: 60
EXOATMOSPHERIC TEMPERATURE(K): 1500.0
DAY-NIGHT PARAMETER: NIGHT

ALT(KM)	TEMP(K)	TOTAL NUMBER DENSITY(MOLEC/CM3)									
		O2	O	CH4	CO2	H2O	NO	N2O	CO	N2	O3
60.0	250.8	.107E+16	.100E+07	.476E+14	.160E+13	.246E+11	.900E+08	.509E+11	713E+09	.398E+16	.733E
62.0	246.9	.828E+15	.251E+07	.369E+14	.124E+13	.188E+11	.720E+08	395E+11	.790E+09	.309E+16	.481E
64.0	242.9	.640E+15	.631E+07	.285E+14	.959E+12	.143E+11	.580E+08	.305E+11	.855E+09	.239E+16	.317E
66.0	238.9	.493E+15	.158E+08	.220E+14	.739E+12	.106E+11	.460E+08	.235E+11	.941E+09	.184E+16	.180E
68.0	234.8	.378E+15	.398E+08	.169E+14	.567E+12	.797E+10	.370E+08	.180E+11	.975E+09	.141E+16	.870E
70.0	230.7	.289E+15	.100E+09	.129E+14	.433E+12	.586E+10	.290E+08	.138E+11	.965E+09	.108E+16	.380E
72.0	226.6	.219E+15	.251E+09	.978E+13	.329E+12	.428E+10	.230E+08	.105E+11	.101E+10	.818E+15	.160E
74.0	222.5	.166E+15	.631E+09	.740E+13	.249E+12	.304E+10	.180E+08	.792E+10	.103E+10	.619E+15	.800E
76.0	218.4	.125E+15	.158E+10	.557E+13	.187E+12	.214E+10	.140E+08	.596E+10	.101E+10	.466E+15	.100E
78.0	214.3	.935E+14	.398E+10	.417E+13	.140E+12	.149E+10	.115E+08	.447E+10	.982E+09	.349E+15	.150E
80.0	210.2	.697E+14	.100E+11	.311E+13	.104E+12	.998E+09	.960E+07	.333E+10	.998E+09	.260E+15	.210E
82.0	206.1	.516E+14	.205E+11	.230E+13	.773E+11	.636E+09	.870E+07	.246E+10	.103E+10	.192E+15	.250E
84.0	201.9	.380E+14	.420E+11	.169E+13	.569E+11	.393E+09	.820E+07	.181E+10	.997E+09	.142E+15	.280E
86.0	199.6	.276E+14	.860E+11	.123E+13	.413E+11	.241E+09	.870E+07	.132E+10	.103E+10	.103E+15	.260E
88.0	198.6	.198E+14	.151E+12	.881E+12	.296E+11	.142E+09	.105E+08	.944E+09	.991E+09	.737E+14	.220E
90.0	199.6	.142E+14	.244E+12	.632E+12	.212E+11	.846E+08	.140E+08	.677E+09	.101E+10	.528E+14	.180E
92.0	201.6	.101E+14	.343E+12	.450E+12	.151E+11	.461E+08	.180E+08	.481E+09	.101E+10	.376E+14	.130E
94.0	207.0	.709E+13	.416E+12	.316E+12	.106E+11	.254E+08	.230E+08	.339E+09	.948E+09	.264E+14	.920E
96.0	212.4	.504E+13	.447E+12	.225E+12	.755E+10	.130E+08	.300E+08	.241E+09	.866E+09	.188E+14	.620E
98.0	217.9	.361E+13	.448E+12	.161E+12	.541E+10	.575E+07	.360E+08	.172E+09	.793E+09	.135E+14	.400E
100.0	223.3	.261E+13	.430E+12	.116E+12	.391E+10	.259E+07	.400E+08	.125E+09	.747E+09	.972E+13	.260E
102.0	229.8	.189E+13	.401E+12	.844E+11	.284E+10	.151E+07	.420E+08	.904E+08	.633E+09	.706E+13	.189E
104.0	240.3	.137E+13	.362E+12	.609E+11	.205E+10	.978E+06	.440E+08	.652E+08	.522E+09	.509E+13	.136E
106.0	250.9	.999E+12	.319E+12	.446E+11	.150E+10	.656E+06	.450E+08	.477E+08	.429E+09	.373E+13	.996E
108.0	261.4	.741E+12	.275E+12	.330E+11	.111E+10	.457E+06	.440E+08	.354E+08	.340E+09	.276E+13	.738E
110.0	272.0	.556E+12	.230E+12	.248E+11	.833E+09	.332E+06	.420E+08	.265E+08	.265E+09	.207E+13	.554E
112.0	282.6	.411E+12	.189E+12	.172E+11	.559E+09	.275E+06	.390E+08	.200E+08	.203E+09	.158E+13	.359E
114.0	295.4	.306E+12	.156E+12	.120E+11	.378E+09	.229E+06	.350E+08	.151E+08	.156E+09	.122E+13	.236E
116.0	308.2	.230E+12	.130E+12	.851E+10	.260E+09	.191E+06	.310E+08	.115E+08	.121E+09	.943E+12	.157E
118.0	321.0	.175E+12	.110E+12	.612E+10	.182E+09	.161E+06	.270E+08	.891E+07	.947E+08	.740E+12	.107E
120.0	333.3	.135E+12	.928E+11	.447E+10	.129E+09	.137E+06	.230E+08	.696E+07	.751E+08	.586E+12	.736E
122.0	371.6	.987E+11	.763E+11	.310E+10	.870E+08	.109E+06	.204E+08	.515E+07	.562E+08	.439E+12	.485E
124.0	409.9	.743E+11	.627E+11	.223E+10	.610E+08	.893E+05	.181E+08	.392E+07	.433E+08	.338E+12	.332E
126.0	446.5	.576E+11	.527E+11	.165E+10	.444E+08	.745E+05	.159E+08	.307E+07	.343E+08	.268E+12	.237E
128.0	481.4	.457E+11	.453E+11	.126E+10	.332E+08	.633E+05	.138E+08	.246E+07	.277E+08	.216E+12	.174E
130.0	516.3	.368E+11	.390E+11	.981E+09	.253E+08	.544E+05	.120E+08	.200E+07	.228E+08	.178E+12	.130E
132.0	547.6	.303E+11	.345E+11	.780E+09	.198E+08	.475E+05	.104E+08	.166E+07	.190E+08	.149E+12	.100E
134.0	578.9	.252E+11	.305E+11	.628E+09	.157E+08	.418E+05	.909E+07	.139E+07	.161E+08	.126E+12	.780E
136.0	608.9	.212E+11	.273E+11	.513E+09	.126E+08	.371E+05	.792E+07	.118E+07	.138E+08	.107E+12	.617E
138.0	637.8	.180E+11	.246E+11	.424E+09	.103E+08	.332E+05	.689E+07	.101E+07	.119E+08	.926E+11	.495E
140.0	666.6	.154E+11	.222E+11	.353E+09	.844E+07	.298E+05	.600E+07	.871E+06	.103E+08	.804E+11	.401E
142.0	693.0	.134E+11	.203E+11	.297E+09	.701E+07	.270E+05	.521E+07	.759E+06	.903E+07	.705E+11	.329E
144.0	719.4	.116E+11	.186E+11	.252E+09	.587E+07	.246E+05	.452E+07	.664E+06	.795E+07	.621E+11	.272E

146.0	744.8	.102E+11	.171E+11	.215E+09	.495E+07	.224E+05	.392E+07	.585E+06	.705E+07	.550E+11	227E
148.0	769.2	.895E+10	.157E+11	.185E+09	.420E+07	.206E+05	.340E+07	.518E+06	.628E+07	.490E+11	.190E
150.0	793.6	.791E+10	.145E+11	.160E+09	.359E+07	190E+05	.295E+07	.460E+06	.561E+07	438E+11	.161E
160.0	901.6	.455E+10	.104E+11	.829E+08	.176E+07	.131E+05	160E+07	272E+06	341E+07	266E+11	.748E
170.0	995.6	.283E+10	.777E+10	.468E+08	.950E+06	.962E+04	.959E+06	.173E+06	.222E+07	173E+11	.384E
180.0	1077.0	.185E+10	.605E+10	.282E+08	.546E+06	.732E+04	.575E+06	.116E+06	.152E+07	.118E+11	.212E
190.0	1147.8	.126E+10	.484E+10	.177E+08	.330E+06	.574E+04	.368E+06	.804E+05	.107E+07	.839E+10	.123E
200.0	1209.2	.886E+09	.395E+10	.115E+08	.207E+06	.460E+04	.235E+06	.576E+05	784E+06	.612E+10	.743E
210.0	1257.4	.639E+09	.331E+10	.776E+07	.134E+06	.376E+04	.160E+06	.423E+05	.586E+06	.458E+10	465E
220.0	1305.6	.468E+09	.277E+10	.530E+07	.885E+05	.310E+04	.109E+06	.315E+05	444E+06	.346E+10	.296E
230.0	1347.8	.348E+09	.234E+10	.369E+07	.596E+05	.259E+04	.743E+05	238E+05	.341E+06	266E+10	.193E
240.0	1383.9	.262E+09	.201E+10	.261E+07	.408E+05	.218E+04	.506E+05	.182E+05	.265E+06	.207E+10	128E
250.0	1420.0	199E+09	.173E+10	.186E+07	.282E+05	.185E+04	.345E+05	.140E+05	208E+06	162E+10	.857E
260.0	1432.8	.154E+09	.152E+10	.136E+07	.200E+05	.160E+04	.244E+05	.111E+05	166E+06	130E+10	.588E
270.0	1445.6	.120E+09	.133E+10	.997E+06	.142E+05	.138E+04	.173E+05	875E+04	133E+06	.104E+10	406E
280.0	1455.8	.940E+08	.117E+10	.735E+06	.102E+05	120E+04	.123E+05	694E+04	107E+06	839E+09	282E
290.0	1463.5	.738E+08	.104E+10	.544E+06	.730E+04	.104E+04	.868E+04	553E+04	869E+05	.678E+09	.197E
300.0	1471.2	.581E+08	.915E+09	.404E+06	.526E+04	.910E+03	.615E+04	.442E+04	.704E+05	.550E+09	.138E

AFGL SPECIES INDEX NUMBER FOR ATMOSPHERIC SPECIES

ATMOSPHERIC SPECIES	AFGL NUMBER
1	7
2	30
3	6
4	2
5	1
6	8
7	4
8	5
9	22
10	3

CO RADIATIVE PROPERTIES

STATE	ENERGY(CM-1)	DEGENERACY
CO(0)	.000	1.
CO(1)	2143.272	1.
CO(2)	4260.063	1.

TRANSITION		FREQUENCY(CM-1)	ESHINE T(K)	RADIANCE
CO(1)	-CO(0)	2143.272	230.0	Y
CO(2)	-CO(0)	4260.063	280.0	Y
CO(2)	-CO(1)	2116.791	280.0	Y

TRANSITION		NO. OF LINES	AVERAGE STRENGTH (CM-1/MOLEC-CM-2)	DISTRIBUTION
CO(1)	-CO(0)			
		2.	.506E-18	.103E+00
		21.	.350E-18	.851E+00
		7.	.136E-18	.948E+00
		4.	.710E-19	.977E+00
		5.	.313E-19	.993E+00
		2.	.142E-19	.996E+00
		4.	.716E-20	.999E+00
		2.	.322E-20	.999E+00
		3.	.162E-20	.100E+01
		7.	.441E-21	.100E+01
CO(2)	-CO(0)			
		18.	.307E-20	.734E+00
		8.	.157E-20	.901E+00
		6.	.802E-21	.965E+00
		5.	.349E-21	.988E+00
		3.	.156E-21	.994E+00
		3.	.773E-22	.997E+00
		4.	.336E-22	.999E+00
		2.	.145E-22	.100E+01
		3.	.725E-23	.100E+01
		7.	.178E-23	.100E+01
CO(2)	-CO(1)			
		1.	.101E-17	.526E-01
		18.	.766E-18	.774E+00
		10.	.326E-18	.945E+00
		4.	.144E-18	.975E+00
		3.	.768E-19	.987E+00
		5.	.386E-19	.997E+00
		4.	.149E-19	.100E+01

NEMESIS OUTPUT FOR CO(1) -CO(0)

EARTHSHINE FLUX(PHOTONS/SEC/CM2/CM-1):	.130E+13
SOLAR FLUX(PHOTONS/SEC/CM2/CM-1):	.000E+00
EINSTEIN A COEFFICIENT(1/SEC):	.310E+02
SUM OF EINSTEIN A COEFFICIENTS(1/SEC):	.310E+02
TOTAL NUMBER OF PHOTONS:	10000
MAXIMUM ORDER OF SCATTERING:	200

ALT(KM)	POPULATIONS(MOLEC/CM3)			PROBABILITIES		QUENCHING	EXCITATION RATES(1/SEC)		
	LOWER STATE	UPPER STATE		RE-EMISSION	ESCAPE	RATE(1/SEC)	EARTH	SUN	ATMOSPHERE
		INITIAL	FINAL						
.610E+02	.752E+09	.141E+04	.155E+04	.684E+00	.978E+00	.143E+02	.256E-04	.000E+00	.699E-05
.630E+02	.823E+09	.122E+04	.139E+04	.744E+00	.977E+00	.107E+02	.255E-04	.000E+00	.763E-05
.650E+02	.898E+09	.109E+04	.130E+04	.797E+00	.974E+00	.790E+01	.252E-04	.000E+00	.789E-05
.670E+02	.958E+09	.982E+03	.122E+04	.842E+00	.974E+00	.582E+01	.248E-04	.000E+00	.817E-05
.690E+02	.970E+09	.878E+03	.113E+04	.879E+00	.974E+00	.426E+01	.244E-04	.000E+00	.831E-05
.710E+02	.985E+09	.817E+03	.109E+04	.909E+00	.974E+00	.310E+01	.239E-04	.000E+00	.843E-05
.730E+02	.102E+10	.794E+03	.108E+04	.932E+00	.973E+00	.225E+01	.235E-04	.000E+00	.848E-05
.750E+02	.102E+10	.763E+03	.106E+04	.950E+00	.971E+00	.162E+01	.230E-04	.000E+00	.852E-05
.770E+02	.998E+09	.722E+03	.102E+04	.964E+00	.972E+00	.115E+01	.225E-04	.000E+00	.859E-05
.790E+02	.990E+09	.698E+03	.992E+03	.974E+00	.972E+00	.819E+00	.220E-04	.000E+00	.858E-05
.810E+02	.102E+10	.701E+03	.100E+04	.982E+00	.973E+00	.577E+00	.216E-04	.000E+00	.860E-05
.830E+02	.102E+10	.687E+03	.991E+03	.987E+00	.970E+00	.404E+00	.211E-04	.000E+00	.849E-05
.850E+02	.101E+10	.670E+03	.972E+03	.991E+00	.973E+00	.283E+00	.206E-04	.000E+00	.852E-05
.870E+02	.101E+10	.656E+03	.954E+03	.994E+00	.973E+00	.201E+00	.202E-04	.000E+00	.843E-05
.890E+02	.100E+10	.639E+03	.933E+03	.995E+00	.971E+00	.144E+00	.198E-04	.000E+00	.827E-05
.910E+02	.101E+10	.632E+03	.924E+03	.997E+00	.972E+00	.104E+00	.194E-04	.000E+00	.817E-05
.930E+02	.979E+09	.600E+03	.878E+03	.997E+00	.975E+00	.778E-01	.190E-04	.000E+00	.810E-05
.950E+02	.907E+09	.545E+03	.798E+03	.998E+00	.976E+00	.591E-01	.186E-04	.000E+00	.798E-05
.970E+02	.829E+09	.490E+03	.716E+03	.999E+00	.978E+00	.452E-01	.183E-04	.000E+00	.789E-05
.990E+02	.770E+09	.447E+03	.655E+03	.999E+00	.977E+00	.348E-01	.180E-04	.000E+00	.775E-05
.101E+03	.690E+09	.395E+03	.577E+03	.999E+00	.978E+00	.270E-01	.177E-04	.000E+00	.762E-05
.103E+03	.577E+09	.326E+03	.476E+03	.999E+00	.983E+00	.215E-01	.175E-04	.000E+00	.759E-05
.105E+03	.476E+09	.267E+03	.388E+03	.999E+00	.986E+00	.175E-01	.173E-04	.000E+00	.754E-05
.107E+03	.385E+09	.214E+03	.311E+03	.100E+01	.986E+00	.143E-01	.171E-04	.000E+00	.744E-05
.109E+03	.303E+09	.167E+03	.242E+03	.100E+01	.991E+00	.118E-01	.170E-04	.000E+00	.745E-05
.111E+03	.234E+09	.129E+03	.187E+03	.100E+01	.992E+00	.985E-02	.169E-04	.000E+00	.741E-05
.113E+03	.179E+09	.988E+02	.143E+03	.100E+01	.993E+00	.833E-02	.169E-04	.000E+00	.738E-05
.115E+03	.138E+09	.762E+02	.110E+03	.100E+01	.995E+00	.713E-02	.168E-04	.000E+00	.740E-05
.117E+03	.108E+09	.596E+02	.857E+02	.100E+01	.996E+00	.614E-02	.168E-04	.000E+00	.739E-05
.119E+03	.849E+08	.471E+02	.676E+02	.100E+01	.997E+00	.532E-02	.167E-04	.000E+00	.739E-05
.121E+03	.657E+08	.371E+02	.529E+02	.100E+01	.997E+00	.492E-02	.167E-04	.000E+00	.740E-05
.123E+03	.498E+08	.297E+02	.417E+02	.100E+01	.998E+00	.478E-02	.167E-04	.000E+00	.741E-05
.125E+03	.388E+08	.253E+02	.346E+02	.100E+01	.998E+00	.468E-02	.167E-04	.000E+00	.742E-05
.127E+03	.310E+08	.227E+02	.302E+02	.100E+01	.999E+00	.462E-02	.167E-04	.000E+00	.743E-05
.129E+03	.252E+08	.214E+02	.275E+02	.100E+01	.999E+00	.461E-02	.167E-04	.000E+00	.745E-05
.131E+03	.209E+08	.207E+02	.258E+02	.100E+01	.999E+00	.463E-02	.167E-04	.000E+00	.746E-05
.133E+03	.176E+08	.206E+02	.249E+02	.100E+01	.999E+00	.467E-02	.166E-04	.000E+00	.747E-05
.135E+03	.149E+08	.207E+02	.244E+02	.100E+01	.999E+00	.475E-02	.166E-04	.000E+00	.748E-05
.137E+03	.128E+08	.211E+02	.242E+02	.100E+01	.999E+00	.484E-02	.166E-04	.000E+00	.750E-05
.139E+03	.111E+08	.216E+02	.243E+02	.100E+01	.999E+00	.496E-02	.166E-04	.000E+00	.751E-05

.141E+03	.967E+07	.222E+02	.245E+02	.100E+01	.999E+00	.508E-02	.166E-04	.000E+00	.752E-05
.143E+03	.849E+07	.227E+02	.248E+02	.100E+01	.100E+01	.522E-02	.166E-04	.000E+00	.753E-05
.145E+03	.750E+07	.232E+02	.251E+02	.100E+01	.100E+01	.535E-02	.166E-04	.000E+00	.752E-05
.147E+03	.666E+07	.237E+02	.253E+02	.100E+01	.100E+01	.549E-02	.166E-04	.000E+00	.753E-05
.149E+03	.595E+07	.240E+02	.255E+02	.100E+01	.100E+01	.562E-02	.166E-04	.000E+00	.754E-05
.155E+03	.451E+07	.259E+02	.270E+02	.100E+01	.999E+00	.613E-02	.166E-04	.000E+00	.742E-05
.165E+03	.281E+07	.250E+02	.257E+02	.100E+01	.999E+00	.669E-02	.166E-04	.000E+00	.745E-05
.175E+03	.187E+07	.227E+02	.232E+02	.100E+01	.100E+01	.707E-02	.166E-04	.000E+00	.740E-05
.185E+03	.130E+07	.197E+02	.200E+02	.100E+01	.100E+01	.728E-02	.166E-04	.000E+00	.742E-05
.195E+03	.929E+06	.165E+02	.167E+02	.100E+01	.100E+01	.732E-02	.166E-04	.000E+00	.745E-05
.205E+03	.685E+06	.134E+02	.135E+02	.100E+01	.100E+01	.719E-02	.166E-04	.000E+00	.747E-05
.215E+03	.515E+06	.107E+02	.108E+02	100E+01	.100E+01	.696E-02	.166E-04	.000E+00	.747E-05
.225E+03	.392E+06	.848E+01	.858E+01	.100E+01	.100E+01	.669E-02	.166E-04	.000E+00	.749E-05
.235E+03	.303E+06	.567E+01	.674E+01	.100E+01	.100E+01	.638E-02	.166E-04	.000E+00	.749E-05
.245E+03	.236E+06	.523E+01	.529E+01	.100E+01	.100E+01	.605E-02	.166E-04	.000E+00	.749E-05
.255E+03	.187E+06	.398E+01	.403E+01	.100E+01	.100E+01	.560E-02	.166E-04	.000E+00	.750E-05
.265E+03	.150E+06	.296E+01	.300E+01	.100E+01	.100E+01	.509E-02	.166E-04	.000E+00	.750E-05
.275E+03	.120E+06	.220E+01	.223E+01	.100E+01	.100E+01	.461E-02	.166E-04	.000E+00	.750E-05
.285E+03	.972E+05	.162E+01	.165E+01	.100E+01	.100E+01	.415E-02	.166E-04	.000E+00	.749E-05
.295E+03	.787E+05	.120E+01	.122E+01	.100E+01	.100E+01	.374E-02	.166E-04	.000E+00	.749E-05

EXCITED STATE NUMBER DENSITIES(MOLEC/CM3)

ALT(KM)	CO(0)	CO(1)	CO(2)
61.0	.752E+09	.155E+04	.905E-09
63.0	.823E+09	.139E+04	.435E-09
65.0	.898E+09	.130E+04	.207E-09
67.0	.958E+09	.122E+04	.965E-10
69.0	.970E+09	.113E+04	.455E-10
71.0	.985E+09	.109E+04	.261E-10
73.0	.102E+10	.108E+04	.217E-10
75.0	.102E+10	.106E+04	.250E-10
77.0	.998E+09	.102E+04	.338E-10
79.0	.990E+09	.992E+03	.494E-10
81.0	.102E+10	.100E+04	.661E-10
83.0	.102E+10	.991E+03	.812E-10
85.0	.101E+10	.972E+03	.110E-09
87.0	.101E+10	.954E+03	.175E-09
89.0	.100E+10	.933E+03	.286E-09
91.0	.101E+10	.924E+03	.475E-09
93.0	.979E+09	.878E+03	.923E-09
95.0	.907E+09	.798E+03	.187E-08
97.0	.829E+09	.716E+03	.343E-08
99.0	.770E+09	.655E+03	.605E-08
101.0	.690E+09	.577E+03	.106E-07
103.0	.577E+09	.476E+03	.231E-07
105.0	.476E+09	.388E+03	.601E-07
107.0	.385E+09	.311E+03	.142E-06
109.0	.303E+09	.242E+03	.301E-06
111.0	.234E+09	.187E+03	.572E-06
113.0	.179E+09	.143E+03	.111E-05
115.0	.138E+09	.110E+03	.222E-05
117.0	.108E+09	.857E+02	.420E-05
119.0	.849E+08	.676E+02	.736E-05
121.0	.657E+08	.529E+02	.276E-04
123.0	.498E+08	.417E+02	.166E-03
125.0	.388E+08	.346E+02	.686E-03
127.0	.310E+08	.302E+02	.212E-02
129.0	.252E+08	.275E+02	.539E-02
131.0	.209E+08	.258E+02	.115E-01
133.0	.176E+08	.248E+02	.213E-01
135.0	.149E+08	.244E+02	.362E-01
137.0	.128E+08	.242E+02	.569E-01
139.0	.111E+08	.243E+02	.843E-01
141.0	.967E+07	.245E+02	.118E+00
143.0	.849E+07	.248E+02	.157E+00
145.0	.750E+07	.251E+02	.203E+00
147.0	.666E+07	.253E+02	.253E+00
149.0	.595E+07	.255E+02	.307E+00
155.0	.451E+07	.270E+02	.498E+00
165.0	.281E+07	.257E+02	.775E+00
175.0	.187E+07	.232E+02	.958E+00
185.0	.130E+07	.200E+02	.103E+01

195.0	.929E+06	.167E+02	.101E+01
205.0	.685E+06	.135E+02	.917E+00
215.0	.515E+06	.108E+02	.800E+00
225.0	.392E+06	.858E+01	.684E+00
235.0	.303E+06	.674E+01	.570E+00
245.0	.236E+06	.529E+01	.471E+00
255.0	.187E+06	.403E+01	.370E+00
265.0	.150E+06	.300E+01	.279E+00
275.0	.120E+06	.223E+01	.210E+00
285.0	.972E+05	.165E+01	.156E+00
295.0	.787E+05	.122E+01	.116E+00

NEMESIS OUTPUT FOR CO(2) -CO(0)

EARTHSHINE FLUX(PHOTONS/SEC/CM2/CM-1):	.106E+10
SOLAR FLUX(PHOTONS/SEC/CM2/CM-1):	.000E+00
EINSTEIN A COEFFICIENT(1/SEC):	.103E+01
SUM OF EINSTEIN A COEFFICIENTS(1/SEC):	.615E+02
TOTAL NUMBER OF PHOTONS:	10000
MAXIMUM ORDER OF SCATTERING:	200

ALT(KM)	POPULATIONS(MOLEC/CM3)			PROBABILITIES		QUENCHING	EXCITATION RATES(1/SEC)		
	LOWER STATE	UPPER STATE		RE-EMISSION	ESCAPE	RATE(1/SEC)	EARTH	SUN	ATMOSPHERE
		INITIAL	FINAL						
.610E+02	.752E+09	.196E-02	.196E-02	.168E-01	.100E+01	.494E-05	.160E-09	.000E+00	.332E-17
.630E+02	.823E+09	.215E-02	.215E-02	.168E-01	.100E+01	.322E-05	.160E-09	.000E+00	-.815E-17
.650E+02	.898E+09	.234E-02	.234E-02	.168E-01	.100E+01	.209E-05	.160E-09	.000E+00	.403E-17
.670E+02	.958E+09	.250E-02	.250E-02	.168E-01	.100E+01	.137E-05	.160E-09	.000E+00	-.339E-17
.690E+02	.970E+09	.253E-02	.253E-02	.168E-01	.100E+01	.950E-06	.160E-09	.000E+00	.677E-17
.710E+02	.985E+09	.257E-02	.257E-02	.168E-01	.100E+01	.797E-06	.160E-09	.000E+00	-.833E-18
.730E+02	.102E+10	.265E-02	.265E-02	.168E-01	.100E+01	.952E-06	.160E-09	.000E+00	-.376E-17
.750E+02	.102E+10	.267E-02	.267E-02	.168E-01	.100E+01	.161E-05	.160E-09	.000E+00	.293E-17
.770E+02	.998E+09	.260E-02	.260E-02	.168E-01	.100E+01	.326E-05	.160E-09	.000E+00	.570E-17
.790E+02	.990E+09	.258E-02	.258E-02	.168E-01	.100E+01	.704E-05	.160E-09	.000E+00	-.569E-17
.810E+02	.102E+10	.265E-02	.265E-02	.168E-01	.100E+01	.134E-04	.160E-09	.000E+00	-.221E-17
.830E+02	.102E+10	.265E-02	.265E-02	.168E-01	.100E+01	.240E-04	.160E-09	.000E+00	.680E-17
.850E+02	.101E+10	.264E-02	.264E-02	.168E-01	.100E+01	.442E-04	.160E-09	.000E+00	.464E-17
.870E+02	.101E+10	.263E-02	.263E-02	.168E-01	.100E+01	.787E-04	.160E-09	.000E+00	.626E-17
.890E+02	.100E+10	.262E-02	.262E-02	.168E-01	.100E+01	.131E-03	.160E-09	.000E+00	-.468E-17
.910E+02	.101E+10	.264E-02	.264E-02	.168E-01	.100E+01	.201E-03	.160E-09	.000E+00	.390E-18
.930E+02	.979E+09	.255E-02	.255E-02	.168E-01	.100E+01	.294E-03	.160E-09	.000E+00	.678E-17
.950E+02	.907E+09	.237E-02	.237E-02	.168E-01	.100E+01	.398E-03	.160E-09	.000E+00	-.259E-17
.970E+02	.829E+09	.216E-02	.216E-02	.168E-01	.100E+01	.489E-03	.160E-09	.000E+00	.558E-17
.990E+02	.770E+09	.201E-02	.201E-02	.168E-01	.100E+01	.564E-03	.160E-09	.000E+00	-.753E-17
.101E+03	.690E+09	.180E-02	.180E-02	.168E-01	.100E+01	.635E-03	.160E-09	.000E+00	-.445E-17
.103E+03	.577E+09	.150E-02	.150E-02	.168E-01	.100E+01	.738E-03	.160E-09	.000E+00	-.390E-18
.105E+03	.476E+09	.124E-02	.124E-02	.168E-01	.100E+01	.870E-03	.160E-09	.000E+00	.724E-17
.107E+03	.385E+09	.100E-02	.100E-02	.168E-01	.100E+01	.987E-03	.160E-09	.000E+00	-.477E-17
.109E+03	.303E+09	.789E-03	.789E-03	.168E-01	.100E+01	.108E-02	.160E-09	.000E+00	-.449E-17
.111E+03	.234E+09	.611E-03	.611E-03	.168E-01	.100E+01	.113E-02	.160E-09	.000E+00	-.393E-17
.113E+03	.179E+09	.469E-03	.469E-03	.168E-01	.100E+01	.119E-02	.160E-09	.000E+00	-.123E-17
.115E+03	.138E+09	.363E-03	.363E-03	.168E-01	.100E+01	.128E-02	.160E-09	.000E+00	.572E-17
.117E+03	.108E+09	.285E-03	.285E-03	.168E-01	.100E+01	.137E-02	.160E-09	.000E+00	-.427E-17
.119E+03	.849E+08	.229E-03	.229E-03	.168E-01	.100E+01	.145E-02	.160E-09	.000E+00	-.206E-17
.121E+03	.657E+08	.199E-03	.199E-03	.168E-01	.100E+01	.183E-02	.160E-09	.000E+00	.293E-17
.123E+03	.498E+08	.295E-03	.295E-03	.168E-01	.100E+01	.265E-02	.160E-09	.000E+00	.141E-16
.125E+03	.388E+08	.787E-03	.787E-03	.168E-01	.100E+01	.358E-02	.160E-09	.000E+00	-.339E-17
.127E+03	.310E+08	.220E-02	.220E-02	.168E-01	.100E+01	.460E-02	.160E-09	.000E+00	.258E-16
.129E+03	.252E+08	.546E-02	.546E-02	.168E-01	.100E+01	.570E-02	.160E-09	.000E+00	.543E-15
.131E+03	.209E+08	.115E-01	.115E-01	.168E-01	.100E+01	.680E-02	.160E-09	.000E+00	-.728E-15
.133E+03	.176E+08	.213E-01	.213E-01	.168E-01	.100E+01	.792E-02	.160E-09	.000E+00	.328E-15
.135E+03	.149E+08	.362E-01	.362E-01	.168E-01	.100E+01	.905E-02	.160E-09	.000E+00	.177E-14
.137E+03	.128E+08	.569E-01	.569E-01	.168E-01	.100E+01	.102E-01	.160E-09	.000E+00	-.700E-14
.139E+03	.111E+08	.843E-01	.843E-01	.168E-01	.100E+01	.113E-01	.160E-09	.000E+00	.112E-13

.141E+03	.967E+07	.118E+00	.118E+00	.168E-01	.100E+01	.124E-01	.160E-09	.000E+00	-.223E-13
.143E+03	.849E+07	.158E+00	.158E+00	.167E-01	.100E+01	.134E-01	.160E-09	.000E+00	.530E-13
.145E+03	.750E+07	.203E+00	.203E+00	.167E-01	.100E+01	.144E-01	.160E-09	.000E+00	-.451E-13
.147E+03	.666E+07	.253E+00	.253E+00	.167E-01	.100E+01	.153E-01	.160E-09	.000E+00	.938E-14
.149E+03	.595E+07	.307E+00	.307E+00	.167E-01	.100E+01	.162E-01	.160E-09	.000E+00	-.737E-13
.155E+03	.451E+07	.498E+00	.498E+00	.167E-01	.100E+01	.188E-01	.160E-09	.000E+00	-.299E-14
.165E+03	.281E+07	.775E+00	.775E+00	.167E-01	.100E+01	.217E-01	.160E-09	.000E+00	-.118E-12
.175E+03	.187E+07	.958E+00	.958E+00	.167E-01	.100E+01	.234E-01	.160E-09	.000E+00	-.869E-12
.185E+03	.130E+07	.103E+01	.103E+01	.167E-01	.100E+01	.242E-01	.160E-09	.000E+00	.550E-12
.195E+03	.929E+06	.101E+01	.101E+01	.167E-01	.100E+01	.243E-01	.160E-09	.000E+00	.300E-11
.205E+03	.685E+06	.917E+00	.917E+00	.167E-01	.100E+01	.237E-01	.160E-09	.000E+00	.973E-12
.215E+03	.515E+06	.800E+00	.800E+00	.167E-01	.100E+01	.228E-01	.160E-09	.000E+00	.355E-11
.225E+03	.392E+06	.684E+00	.684E+00	.167E-01	.100E+01	.218E-01	.160E-09	.000E+00	-.224E-11
.235E+03	.303E+06	.570E+00	.570E+00	.167E-01	.100E+01	.206E-01	.160E-09	.000E+00	.584E-11
.245E+03	.236E+06	.471E+00	.471E+00	.167E-01	.100E+01	.194E-01	.160E-09	.000E+00	.478E-12
.255E+03	.187E+06	.370E+00	.370E+00	.167E-01	.100E+01	.179E-01	.160E-09	.000E+00	-.126E-11
.265E+03	.150E+06	.279E+00	.279E+00	.167E-01	.100E+01	.162E-01	.160E-09	.000E+00	-.524E-11
.275E+03	.120E+06	.210E+00	.210E+00	.167E-01	.100E+01	.146E-01	.160E-09	.000E+00	-.339E-11
.285E+03	.972E+05	.156E+00	.156E+00	.167E-01	.100E+01	.132E-01	.160E-09	.000E+00	.140E-11
.295E+03	.787E+05	.116E+00	.116E+00	.168E-01	.100E+01	.118E-01	.160E-09	.000E+00	-.319E-12

EXCITED STATE NUMBER DENSITIES(MOLEC/CM3)

ALT(KM)	CO(0)	CO(1)	CO(2)
61.0	.752E+09	.155E+04	.196E-02
63.0	.823E+09	.139E+04	.215E-02
65.0	.898E+09	.130E+04	.234E-02
67.0	.958E+09	.122E+04	.250E-02
69.0	.970E+09	.113E+04	.253E-02
71.0	.985E+09	.109E+04	.257E-02
73.0	.102E+10	.108E+04	.265E-02
75.0	.102E+10	.106E+04	.267E-02
77.0	.998E+09	.102E+04	.260E-02
79.0	.990E+09	.992E+03	.258E-02
81.0	.102E+10	.100E+04	.265E-02
83.0	.102E+10	.991E+03	.265E-02
85.0	.101E+10	.972E+03	.264E-02
87.0	.101E+10	.954E+03	.263E-02
89.0	.100E+10	.933E+03	.262E-02
91.0	.101E+10	.924E+03	.264E-02
93.0	.979E+09	.878E+03	.255E-02
95.0	.907E+09	.798E+03	.237E-02
97.0	.829E+09	.716E+03	.216E-02
99.0	.770E+09	.655E+03	.201E-02
101.0	.690E+09	.577E+03	.180E-02
103.0	.577E+09	.476E+03	.150E-02
105.0	.476E+09	.388E+03	.124E-02
107.0	.385E+09	.311E+03	.100E-02
109.0	.303E+09	.242E+03	.789E-03
111.0	.234E+09	.187E+03	.611E-03
113.0	.179E+09	.143E+03	.469E-03
115.0	.138E+09	.110E+03	.363E-03
117.0	.108E+09	.857E+02	.285E-03
119.0	.849E+08	.676E+02	.229E-03
121.0	.657E+08	.529E+02	.199E-03
123.0	.498E+08	.417E+02	.295E-03
125.0	.388E+08	.346E+02	.787E-03
127.0	.310E+08	.302E+02	.220E-02
129.0	.252E+08	.275E+02	.546E-02
131.0	.209E+08	.258E+02	.115E-01
133.0	.176E+08	.248E+02	.213E-01
135.0	.149E+08	.244E+02	.362E-01
137.0	.128E+08	.242E+02	.569E-01
139.0	.111E+08	.243E+02	.843E-01
141.0	.967E+07	.245E+02	.118E+00
143.0	.849E+07	.248E+02	.158E+00
145.0	.750E+07	.251E+02	.203E+00
147.0	.666E+07	.253E+02	.253E+00
149.0	.595E+07	.255E+02	.307E+00
155.0	.451E+07	.270E+02	.498E+00
165.0	.281E+07	.257E+02	.775E+00
175.0	.187E+07	.232E+02	.958E+00
185.0	.130E+07	.200E+02	.103E+01

195.0	.929E+06	.167E+02	.101E+01
205.0	.685E+06	.135E+02	.917E+00
215.0	.515E+06	.108E+02	.800E+00
225.0	.392E+06	.858E+01	.684E+00
235.0	.303E+06	.674E+01	.570E+00
245.0	.236E+06	.529E+01	.471E+00
255.0	.187E+06	.403E+01	.370E+00
265.0	.150E+06	.300E+01	.279E+00
275.0	.120E+06	.223E+01	.210E+00
285.0	.972E+05	.165E+01	.156E+00
295.0	.787E+05	.122E+01	.116E+00

NEMESIS OUTPUT FOR CO(2) -CO(1)

EARTHSHINE FLUX(PHOTONS/SEC/CM2/CM-1):	.159E+14
SOLAR FLUX(PHOTONS/SEC/CM2/CM-1):	.000E+00
EINSTEIN A COEFFICIENT(1/SEC):	.605E+02
SUM OF EINSTEIN A COEFFICIENTS(1/SEC):	.615E+02
TOTAL NUMBER OF PHOTONS:	10000
MAXIMUM ORDER OF SCATTERING:	200

ALT(KM)	POPULATIONS(MOLEC/CM3)			PROBABILITIES		QUENCHING	EXCITATION RATES(1/SEC)		
	LOWER STATE	UPPER STATE INITIAL	UPPER STATE FINAL	RE-EMISSION	ESCAPE	RATE(1/SEC)	EARTH	SUN	ATMOSPHERE
.610E+02	.155E+04	.173E-01	.173E-01	.983E+00	.100E+01	.494E-05	.610E-03	.000E+00	.811E-11
.630E+02	.139E+04	.160E-01	.160E-01	.983E+00	.100E+01	.322E-05	.610E-03	.000E+00	.262E-11
.650E+02	.130E+04	.152E-01	.152E-01	.983E+00	.100E+01	.209E-05	.610E-03	.000E+00	.179E-10
.670E+02	.122E+04	.146E-01	.146E-01	.983E+00	.100E+01	.137E-05	.610E-03	.000E+00	-.133E-10
.690E+02	.113E+04	.138E-01	.138E-01	.983E+00	.100E+01	.950E-06	.610E-03	.000E+00	-.852E-11
.710E+02	.109E+04	.133E-01	.133E-01	.983E+00	.100E+01	.797E-06	.610E-03	.000E+00	.628E-11
.730E+02	.108E+04	.134E-01	.134E-01	.983E+00	.100E+01	.952E-06	.610E-03	.000E+00	-.233E-10
.750E+02	.106E+04	.132E-01	.132E-01	.983E+00	.100E+01	.161E-05	.610E-03	.000E+00	.162E-10
.770E+02	.102E+04	.127E-01	.127E-01	.983E+00	.100E+01	.326E-05	.610E-03	.000E+00	-.102E-10
.790E+02	.992E+03	.124E-01	.124E-01	.983E+00	.100E+01	.704E-05	.610E-03	.000E+00	.267E-11
.810E+02	.100E+04	.126E-01	.126E-01	.983E+00	.100E+01	.134E-04	.610E-03	.000E+00	-.781E-11
.830E+02	.991E+03	.125E-01	.125E-01	.983E+00	.100E+01	.240E-04	.610E-03	.000E+00	.575E-12
.850E+02	.972E+03	.123E-01	.123E-01	.983E+00	.100E+01	.442E-04	.610E-03	.000E+00	.288E-10
.870E+02	.954E+03	.121E-01	.121E-01	.983E+00	.100E+01	.787E-04	.610E-03	.000E+00	.540E-11
.890E+02	.933E+03	.119E-01	.119E-01	.983E+00	.100E+01	.131E-03	.610E-03	.000E+00	-.202E-11
.910E+02	.924E+03	.118E-01	.118E-01	.983E+00	.100E+01	.201E-03	.610E-03	.000E+00	.305E-10
.930E+02	.878E+03	.113E-01	.113E-01	.983E+00	.100E+01	.294E-03	.610E-03	.000E+00	.145E-10
.950E+02	.798E+03	.103E-01	.103E-01	.983E+00	.100E+01	.398E-03	.610E-03	.000E+00	-.316E-10
.970E+02	.716E+03	.927E-02	.927E-02	.983E+00	.100E+01	.489E-03	.610E-03	.000E+00	.723E-11
.990E+02	.655E+03	.850E-02	.850E-02	.983E+00	.100E+01	.564E-03	.610E-03	.000E+00	.285E-10
.101E+03	.577E+03	.753E-02	.753E-02	.983E+00	.100E+01	.635E-03	.610E-03	.000E+00	.189E-10
.103E+03	.476E+03	.623E-02	.623E-02	.983E+00	.100E+01	.738E-03	.610E-03	.000E+00	.160E-10
.105E+03	.388E+03	.509E-02	.509E-02	.983E+00	.100E+01	.870E-03	.610E-03	.000E+00	.302E-10
.107E+03	.311E+03	.408E-02	.408E-02	.983E+00	.100E+01	.987E-03	.610E-03	.000E+00	-.438E-10
.109E+03	.242E+03	.319E-02	.319E-02	.983E+00	.100E+01	.108E-02	.610E-03	.000E+00	-.527E-11
.111E+03	.187E+03	.246E-02	.246E-02	.983E+00	.100E+01	.113E-02	.610E-03	.000E+00	-.236E-10
.113E+03	.143E+03	.188E-02	.188E-02	.983E+00	.100E+01	.119E-02	.610E-03	.000E+00	.133E-10
.115E+03	.110E+03	.145E-02	.145E-02	.983E+00	.100E+01	.128E-02	.610E-03	.000E+00	-.183E-10
.117E+03	.857E+02	.114E-02	.114E-02	.983E+00	.100E+01	.137E-02	.610E-03	.000E+00	-.144E-10
.119E+03	.676E+02	.899E-03	.899E-03	.983E+00	.100E+01	.145E-02	.610E-03	.000E+00	-.156E-10
.121E+03	.529E+02	.724E-03	.724E-03	.983E+00	.100E+01	.183E-02	.610E-03	.000E+00	.107E-10
.123E+03	.417E+02	.709E-03	.709E-03	.983E+00	.100E+01	.265E-02	.610E-03	.000E+00	.225E-10
.125E+03	.346E+02	.113E-02	.113E-02	.983E+00	.100E+01	.358E-02	.610E-03	.000E+00	.810E-10
.127E+03	.302E+02	.250E-02	.250E-02	.983E+00	.100E+01	.460E-02	.610E-03	.000E+00	.173E-09
.129E+03	.275E+02	.573E-02	.573E-02	.983E+00	.100E+01	.570E-02	.610E-03	.000E+00	.324E-09
.131E+03	.258E+02	.118E-01	.118E-01	.983E+00	.100E+01	.680E-02	.610E-03	.000E+00	-.188E-09
.133E+03	.248E+02	.216E-01	.216E-01	.983E+00	.100E+01	.792E-02	.610E-03	.000E+00	[illegible]
.135E+03	.244E+02	.365E-01	.365E-01	.983E+00	.100E+01	.905E-02	.610E-03	.000E+00	-.119E-08
.137E+03	.242E+02	.571E-01	.571E-01	.983E+00	.100E+01	.102E-01	.610E-03	.000E+00	-.151E-08
.139E+03	.243E+02	.846E-01	.846E-01	.983E+00	.100E+01	.113E-01	.610E-03	.000E+00	470E-08

.141E+03	.245E+02	.118E+00	.118E+00	.983E+00	.100E+01	.124E-01	.610E-03	000E+00	.617E-08
.143E+03	.248E+02	.158E+00	.158E+00	.983E+00	.100E+01	.134E-01	.610E-03	.000E+00	.175E-07
.145E+03	.251E+02	.203E+00	.203E+00	.983E+00	.100E+01	.144E-01	.610E-03	.000E+00	-.131E-08
.147E+03	.253E+02	.253E+00	.253E+00	.983E+00	.100E+01	.153E-01	.610E-03	.000E+00	-.242E-07
.149E+03	.255E+02	.307E+00	.307E+00	.983E+00	.100E+01	.162E-01	.610E-03	.000E+00	-.707E-08
.155E+03	.270E+02	.498E+00	.498E+00	.983E+00	.100E+01	.188E-01	.610E-03	.000E+00	-.306E-07
.165E+03	.257E+02	.775E+00	.775E+00	.983E+00	.100E+01	.217E-01	.610E-03	.000E+00	.276E-07
.175E+03	.232E+02	.958E+00	.958E+00	.983E+00	.100E+01	.234E-01	.610E-03	.000E+00	.178E-07
.185E+03	.200E+02	.103E+01	.103E+01	.983E+00	.100E+01	.242E-01	.610E-03	.000E+00	-.847E-07
.195E+03	.167E+02	.101E+01	.101E+01	.983E+00	.100E+01	.243E-01	.610E-03	.000E+00	.157E-06
.205E+03	.135E+02	.917E+00	.917E+00	.983E+00	.100E+01	.237E-01	.610E-03	.000E+00	-.133E-06
.215E+03	.108E+02	.800E+00	.800E+00	.983E+00	.100E+01	.228E-01	.610E-03	.000E+00	-.104E-06
.225E+03	.858E+01	.684E+00	.684E+00	.983E+00	.100E+01	.218E-01	.610E-03	.000E+00	-.141E-06
.235E+03	.674E+01	.570E+00	.570E+00	.983E+00	.100E+01	.206E-01	.610E-03	.000E+00	-.244E-07
.245E+03	.529E+01	.471E+00	.471E+00	.983E+00	.100E+01	.194E-01	.610E-03	.000E+00	-.730E-07
.255E+03	.403E+01	.370E+00	.370E+00	.983E+00	.100E+01	.179E-01	.610E-03	.000E+00	-.207E-08
.265E+03	.300E+01	.279E+00	.279E+00	.983E+00	.100E+01	.162E-01	.610E-03	.000E+00	-.975E-07
.275E+03	.223E+01	.210E+00	.210E+00	.983E+00	100E+01	.146E-01	.610E-03	.000E+00	.162E-06
.285E+03	.165E+01	.156E+00	.156E+00	.983E+00	.100E+01	.132E-01	.610E-03	.000E+00	.147E-06
.295E+03	.122E+01	.116E+00	.116E+00	.983E+00	.100E+01	.118E-01	.610E-03	.000E+00	.723E-07

EXCITED STATE NUMBER DENSITIES(MOLEC/CM3)

ALT(KM)	CO(0)	CO(1)	CO(2)
61.0	.752E+09	.155E+04	.173E-01
63.0	.823E+09	.139E+04	.160E-01
65.0	.898E+09	.130E+04	.152E-01
67.0	.958E+09	.122E+04	.146E-01
69.0	.970E+09	.113E+04	.138E-01
71.0	.985E+09	.109E+04	.133E-01
73.0	.102E+10	.108E+04	.134E-01
75.0	.102E+10	.106E+04	.132E-01
77.0	.998E+09	.102E+04	.127E-01
79.0	.990E+09	.992E+03	.124E-01
81.0	.102E+10	.100E+04	.126E-01
83.0	.102E+10	.991E+03	.125E-01
85.0	.101E+10	[illegible]	.123E-01
87.0	.101E+10	.954E+03	.121E-01
89.0	.100E+10	.933E+03	.119E-01
91.0	.101E+10	.924E+03	.118E-01
93.0	.979E+09	.878E+03	.113E-01
95.0	.907E+09	.798E+03	.103E-01
97.0	.829E+09	.716E+03	.927E-02
99.0	.770E+09	.655E+03	.850E-02
101.0	.690E+09	.577E+03	.753E-02
103.0	.577E+09	.476E+03	.623E-02
105.0	.476E+09	.388E+03	.509E-02
107.0	.385E+09	.311E+03	.408E-02
109.0	.303E+09	.242E+03	.319E-02
111.0	.234E+09	.187E+03	.246E-02
113.0	.179E+09	.143E+03	.188E-02
115.0	.138E+09	.110E+03	.145E-02
117.0	.108E+09	.857E+02	.114E-02
119.0	.849E+08	.676E+02	.899E-03
121.0	.657E+08	.529E+02	.724E-03
123.0	.498E+08	.417E+02	.709E-03
125.0	.388E+08	.346E+02	.113E-02
127.0	.310E+08	.302E+02	.250E-02
129.0	.252E+08	.275E+02	.573E-02
131.0	.209E+08	.258E+02	.118E-01
133.0	.176E+08	.248E+02	.216E-01
135.0	.149E+08	.244E+02	.365E-01
137.0	.128E+08	.242E+02	.571E-01
139.0	.111E+08	.243E+02	.846E-01
141.0	.967E+07	.245E+02	.118E+00
143.0	.849E+07	.248E+02	.158E+00
145.0	.750E+07	.251E+02	.203E+00
147.0	.666E+07	.253E+02	.253E+00
149.0	.595E+07	.255E+02	.307E+00
155.0	.451E+07	.270E+02	.498E+00
165.0	.281E+07	.257E+02	.775E+00
175.0	.187E+07	.232E+02	.958E+00
185.0	.130E+07	.200E+02	.103E+01

195.0	.929E+06	.167E+02	.101E+01
205.0	.685E+06	.135E+02	.917E+00
215.0	.515E+06	.108E+02	.800E+00
225.0	.392E+06	.858E+01	.684E+00
235.0	.303E+06	.674E+01	.570E+00
245.0	.236E+06	.529E+01	.471E+00
255.0	.187E+06	.403E+01	.370E+00
265.0	.150E+06	.300E+01	.279E+00
275.0	.120E+06	.223E+01	.210E+00
285.0	.972E+05	.165E+01	.156E+00
295.0	.787E+05	.122E+01	.116E+00

VIBRATIONAL TEMPERATURES(K)

ALT(KM)	KINETIC	CO(1)	CO(2)
61.0	248.8	235.5	250.2
63.0	244.9	232.1	248.5
65.0	240.9	229.3	247.1
67.0	236.8	227.2	246.1
69.0	232.7	225.8	245.4
71.0	228.6	224.8	244.9
73.0	224.5	224.2	244.6
75.0	220.4	223.8	244.4
77.0	216.3	223.5	244.3
79.0	212.2	223.2	244.2
81.0	208.1	223.0	244.1
83.0	204.0	222.8	244.0
85.0	200.8	222.6	243.9
87.0	199.6	222.3	243.7
89.0	199.6	222.0	243.6
91.0	200.6	221.7	243.5
93.0	204.3	221.5	243.3
95.0	209.7	221.1	243.2
97.0	215.2	220.9	243.1
99.0	220.6	220.6	242.9
101.0	226.5	220.4	242.8
103.0	235.0	220.1	242.7
105.0	245.6	220.0	242.6
107.0	256.2	219.8	242.6
109.0	266.7	219.7	242.5
111.0	277.3	219.6	242.5
113.0	289.0	219.6	242.5
115.0	301.8	219.5	242.5
117.0	314.6	219.6	242.5
119.0	327.1	219.6	242.5
121.0	352.4	219.8	242.9
123.0	390.7	220.4	245.4
125.0	428.2	221.4	252.7
127.0	463.9	222.8	263.7
129.0	498.8	224.6	276.0
131.0	531.9	276.7	287.8
133.0	563.2	228.9	298.7
135.0	593.9	231.4	309.1
137.0	623.3	234.0	318.8
139.0	652.2	236.7	327.9
141.0	679.8	239.3	336.4
143.0	706.2	242.0	344.3
145.0	732.1	244.6	351.8
147.0	757.0	247.1	358.7
149.0	781.4	249.5	365.3
155.0	847.6	256.4	382.6
165.0	948.6	265.8	405.8
175.0	1036.3	273.0	423.2
185.0	1112.4	278.4	436.5

195.0	1178.5	282.3	445.4
205.0	1233.3	284.7	453.2
215.0	1281.5	286.3	458.2
225.0	1326.7	287.4	462.2
235.0	1365.9	287.8	464.9
245.0	1401.9	288.0	466.9
255.0	1426.4	287.0	466.7
265.0	1439.2	285.0	464.6
275.0	1450.7	282.9	462.2
285.0	1459.7	280.7	459.5
295.0	1467.3	278.4	456.6

LINE-OF-SIGHT GEOMETRY INFORMATION

PATH SELECTION: LIMB VIEWING

TANGENT HEIGHT(KM): 100.00

SEGMENT	LOWER ALT. (KM)	UPPER ALT (KM)	SEGMENT LENGTH(KM)	COLUMN DENSITIES(MOLEC/CM2) CO
1	290.00	300.00	41.65	.3277E+12
2	280.00	290.00	42.72	.4153E+12
3	270.00	280.00	43.87	.5285E+12
4	260.00	270.00	45.13	.6763E+12
5	250.00	260.00	46.51	.8699E+12
6	240.00	250.00	48.03	.1136E+13
7	230.00	240.00	49.73	.1507E+13
8	220.00	230.00	51.62	.2025E+13
9	210.00	220.00	53.76	.2769E+13
10	200.00	210.00	56.20	.3850E+13
11	190.00	200.00	59.02	.5484E+13
12	180.00	190.00	62.33	.8073E+13
13	170.00	180.00	66.29	.1237E+14
14	160.00	170.00	71.14	.2001E+14
15	150.00	160.00	77.27	.3485E+14
16	148.00	150.00	16.34	.9717E+13
17	146.00	148.00	16.69	.1112E+14
18	144.00	146.00	17.05	.1279E+14
19	142.00	144.00	17.44	.1481E+14
20	140.00	142.00	17.85	.1726E+14
21	138.00	140.00	18.30	.2028E+14
22	136.00	138.00	18.78	.2406E+14
23	134.00	136.00	19.31	.2882E+14
24	132.00	134.00	19.88	.3494E+14
25	130.00	132.00	20.51	.4287E+14
26	128.00	130.00	21.20	.5351E+14
27	126.00	128.00	21.97	.6810E+14
28	124.00	126.00	22.82	.8855E+14
29	122.00	124.00	23.79	.1184E+15
30	120.00	122.00	24.89	.1635E+15
31	118.00	120.00	26.17	.2222E+15
32	116.00	118.00	27.66	.2981E+15
33	114.00	116.00	29.44	.4070E+15
34	112.00	114.00	31.62	.5671E+15
35	110.00	112.00	34.38	.8051E+15
36	108.00	110.00	38.02	.1150E+16
37	106.00	108.00	43.14	.1659E+16
38	104.00	106.00	51.16	.2433E+16
39	102.00	104.00	66.66	.3847E+16
40	100.00	102.00	160.40	.1107E+17
41	98.00	100.00	1.00	.7701E+14
42	100.00	102.00	160.40	.1107E+17
43	102.00	104.00	66.66	.3847E+16
44	104.00	106.00	51.16	.2433E+16
45	106.00	108.00	43.14	.1659E+16

46	108.00	110.00	38.02	.1150E+16
47	110.00	112.00	34.38	.8051E+15
48	112.00	114.00	31.62	.5671E+15
49	114 00	116.00	29.44	.4071E+15
50	116.00	118.00	27.66	.2981E+15
51	118.00	120.00	26.17	.2222E+15
52	120.00	122.00	24.89	.1635E+15
53	122.00	124.00	23.79	.1184E+15
54	124.00	126.00	22.82	.8855E+14
55	126.00	128.00	21 97	.6810E+14
56	128.00	130.00	21.20	.5351E+14
57	130.00	132.00	20.51	.4287E+14
58	132.00	134.00	19.88	.3494E+14
59	134.00	136.00	19.31	.2882E+14
60	136.00	138.00	18.78	.2406E+14
61	138.00	140.00	18.30	.2028E+14
62	140.00	142.00	17.85	.1726E+14
63	142.00	144.00	17.44	.1481E+14
64	144.00	146.00	17.05	.1279E+14
65	146.00	148.00	16.69	.1112E+14
66	148.00	150.00	16.34	.9717E+13
67	150.00	160.00	77.27	.3485E+14
68	160.00	170.00	71.14	.2001E+14
69	170.00	180.00	66.29	.1237E+14
70	180.00	190.00	62.33	.8073E+13
71	190.00	200.00	59.02	.5484E+13
72	200.00	210.00	56.20	.3850E+13
73	210.00	220.00	53.76	.2769E+13
74	220.00	230.00	51.62	.2025E+13
75	230.00	240.00	49.73	.1507E+13
76	240.00	250.00	48.03	.1136E+13
77	250.00	260.00	46.51	.8699E+12
78	260.00	270.00	45.13	.6763E+12
79	270.00	280.00	43.87	.5285E+12
80	280.00	290.00	42.72	.4153E+12
81	290.00	300.00	41.65	.3277E+12

81 LAYERS TOTAL PATH LENGTH: 3242.47

SPECTRAL RADIANCE (1.00 CM-1 RESOLUTION)

W(CM-1)	RADIANCE(W/SR/CM2/CM-1)									
1900.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
1910.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
1920.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
1930.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
1940.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
1950.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
1960.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.359E-12
1970.0	.000E+00	.000E+00	.000E+00	.000E+00	.430E-12	.000E+00	.000E+00	.000E+00	.000E+00	.512E-12
1980.0	.000E+00	.000E+00	.000E+00	.000E+00	.608E-12	.000E+00	.000E+00	.000E+00	.000E+00	.720E-12
1990.0	.000E+00	.000E+00	.000E+00	.000E+00	.849E-12	.000E+00	.000E+00	.000E+00	.000E+00	.999E-12
2000.0	.000E+00	.000E+00	.000E+00	.000E+00	.117E-11	.000E+00	.000E+00	.000E+00	.000E+00	.137E-11
2010.0	.000E+00	.000E+00	.000E+00	.161E-11	.000E+00	.000E+00	.000E+00	.000E+00	.188E-11	.000E+00
2020.0	.000E+00	.000E+00	.000E+00	.221E-11	.000E+00	.320E-12	.000E+00	.000E+00	.261E-11	.000E+00
2030.0	.346E-12	.000E+00	.311E-11	.000E+00	.370E-12	.000E+00	.000E+00	.362E-11	.000E+00	.393E-12
2040.0	.000E+00	.000E+00	.447E-11	.414E-12	.000E+00	.000E+00	.563E-11	.433E-12	.000E+00	.000E+00
2050.0	.000E+00	.721E-11	.449E-12	.000E+00	.000E+00	.938E-11	.461E-12	.000E+00	.000E+00	.000E+00
2060.0	.128E-10	.000E+00	.000E+00	.000E+00	.159E-10	.473E-12	.000E+00	.000E+00	.000E+00	.210E-10
2070.0	.000E+00	.000E+00	.000E+00	.266E-10	.000E+00	.000E+00	.000E+00	.452E-12	.322E-10	.000E+00
2080.0	.000E+00	.433E-12	.384E-10	.000E+00	.000E+00	.407E-12	.444E-10	.000E+00	.000E+00	.375E-12
2090.0	.000E+00	.499E-10	.000E+00	.337E-12	.000E+00	.548E-10	.000E+00	.293E-12	.000E+00	.590E-10
2100.0	.000E+00	.243E-12	.000E+00	.625E-10	.000E+00	.187E-12	.000E+00	.653E-10	.000E+00	.128E-13
2110.0	.000E+00	.000E+00	.674E-10	.652E-13	.000E+00	.000E+00	.686E-10	.000E+00	.000E+00	.000E+00
2120.0	.690E-10	.666E-13	.000E+00	.000E+00	.684E-10	.000E+00	.000E+00	.000E+00	.664E-10	.000E+00
2130.0	.000E+00	.000E+00	.623E-10	.000E+00	.000E+00	.324E-12	.543E-10	.000E+00	.000E+00	.387E-10
2140.0	.000E+00	.000E+00	.432E-12	.000E+00	.000E+00	.000E+00	.479E-12	.395E-10	.000E+00	.519E-12
2150.0	.000E+00	.570E-10	.000E+00	.551E-12	.000E+00	.664E-10	.580E-12	.000E+00	.721E-10	.000E+00
2160.0	.600E-12	.000E+00	.759E-10	.613E-12	.000E+00	.000E+00	.788E-10	.000E+00	.000E+00	.794E-10
2170.0	.621E-12	.000E+00	.000E+00	.803E-10	.000E+00	.000E+00	.797E-10	.000E+00	.000E+00	.591E-12
2180.0	.776E-10	.000E+00	.572E-12	.753E-10	.000E+00	.549E-12	.000E+00	.721E-10	.523E-12	.000E+00
2190.0	.680E-10	.495E-12	.000E+00	.629E-10	.465E-12	.000E+00	.000E+00	.569E-10	.000E+00	.000E+00
2200.0	.501E-10	.000E+00	.000E+00	.427E-10	.000E+00	.000E+00	.352E-10	.000E+00	.000E+00	.000E+00
2210.0	.282E-10	.000E+00	.000E+00	.221E-10	.000E+00	.000E+00	.175E-10	.000E+00	.000E+00	.135E-10
2220.0	.000E+00	.000E+00	.105E-10	.000E+00	.000E+00	.827E-11	.000E+00	.000E+00	.667E-11	.000E+00
2230.0	.000E+00	.566E-11	.000E+00	.476E-11	.000E+00	.000E+00	.405E-11	.000E+00	.000E+00	.347E-11
2240.0	.000E+00	.000E+00	.299E-11	.000E+00	.259E-11	.000E+00	.000E+00	.224E-11	.000E+00	.000E+00
2250.0	.194E-11	.000E+00	.168E-11	.000E+00	.000E+00	.145E-11	.000E+00	.124E-11	.000E+00	.000E+00
2260.0	.106E-11	.000E+00	.909E-12	.000E+00	.773E-12	.000E+00	.000E+00	.655E-12	.000E+00	.000E+00
2270.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
.										
.										
4100.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.326E-14
4110.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.374E-14	.000E+00	.000E+00	.000E+00	.000E+00
4120.0	.000E+00	.426E-14	.000E+00	.000E+00	.000E+00	.000E+00	.482E-14	.000E+00	.000E+00	.000E+00
4130.0	.000E+00	.000E+00	.544E-14	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.609E-14	.000E+00
4140.0	.000E+00	.000E+00	.000E+00	.679E-14	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.751E-14
4150.0	.000E+00	.000E+00	.000E+00	.000E+00	.826E-14	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
4160.0	.903E-14	.000E+00	.000E+00	.000E+00	.000E+00	.980E-14	.000E+00	.000E+00	.000E+00	.000E+00
4170.0	.106E-13	.000E+00	.000E+00	.000E+00	.000E+00	.113E-13	.000E+00	.000E+00	.000E+00	.000E+00

4180.0	.120E-13	.000E+00	.000E+00	.000E+00	.000E+00	.126E-13	.000E+00	.000E+00	.000E+00	.000E+00
4190.0	.132E-13	.000E+00	.000E+00	.000E+00	.000E+00	.136E-13	.000E+00	.000E+00	.000E+00	.000E+00
4200.0	.140E-13	.000E+00	.000E+00	.000E+00	.000E+00	.142E-13	.000E+00	.000E+00	.000E+00	.142E-13
4210.0	.000E+00	.000E+00	.000E+00	.000E+00	.141E-13	.000E+00	.000E+00	.000E+00	.138E-13	.000E+00
4220.0	.000E+00	.000E+00	.000E+00	.133E-13	.000E+00	.000E+00	.000E+00	.125E-13	.000E+00	.000E+00
4230.0	.000E+00	.000E+00	.116E-13	.000E+00	.000E+00	.000E+00	.104E-13	.000E+00	.000E+00	.000E+00
4240.0	.910E-14	.000E+00	.000E+00	.000E+00	.756E-14	.000E+00	.000E+00	.000E+00	.586E-14	.000E+00
4250.0	.000E+00	.000E+00	.401E-14	.000E+00	.000E+00	.000E+00	.205E-14	.000E+00	.000E+00	.000E+00
4260.0	.000E+00	.000E+00	.000E+00	.000E+00	.210E-14	.000E+00	.000E+00	.000E+00	.421E-14	.000E+00
4270.0	.000E+00	.629E-14	.000E+00	.000E+00	.000E+00	.830E-14	.000E+00	.000E+00	.102E-13	.000E+00
4280.0	.000E+00	.000E+00	.120E-13	.000E+00	.000E+00	.136E-13	.000E+00	.000E+00	.151E-13	.000E+00
4290.0	.000E+00	.000E+00	.163E-13	.000E+00	.000E+00	.173E-13	.000E+00	.000E+00	.181E-13	.000E+00
4300.0	.000E+00	.187E-13	.000E+00	.000E+00	.191E-13	.000E+00	.193E-13	.000E+00	.000E+00	.192E-13
4310.0	.000E+00	.000E+00	.190E-13	.000E+00	.000E+00	.186E-13	.000E+00	.181E-13	.000E+00	.000E+00
4320.0	.174E-13	.000E+00	.166E-13	.000E+00	.158E-13	.000E+00	.000E+00	.149E-13	.000E+00	.139E-13
4330.0	.000E+00	.129E-13	.000E+00	.119E-13	.000E+00	.109E-13	.000E+00	.997E-14	.000E+00	.904E-14
4340.0	.000E+00	.815E-14	.730E-14	.000E+00	.651E-14	.578E-14	.000E+00	.510E-14	.000E+00	.000E+00
4350.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
4360.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
4370.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
4380.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
4390.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
4400.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
4410.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
4420.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
4430.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
4440.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
4450.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
4460.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
4470.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
4480.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
4490.0	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00	.000E+00
4500.0	.000E+00									

BAND RADIANCE SUMMARY

TRANSITION		FREQUENCY(CM-1)	NO. OF LINES TOTAL	RELAYERED	BAND RADIANCE (W/SR/CM2)
CO(1)	-CO(0)	2143.272	79	50	.23346E-08
CO(2)	-CO(0)	4260.063	64	64	.71067E-12
CO(2)	-CO(1)	2116.791	45	45	.18670E-10
			-----	-----	------------
TOTAL			188	159	.23539E-08

Output file for third test case. This calculation re-uses population file generated by second test case.

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   SSSSSS    HH    HH     AAAAAA     RRRRRR      CCCCCC
  SS         HH    HH   AA    AA   RR    RR    CC
 SS         HH    HH   AA    AA   RR    RR    CC
 SSSSS     HHHHHHHH   AAAAAAAA   RRRRRRR     CC
     SS   HH    HH   AA    AA   RR   RR     CC
    SS   HH    HH   AA    AA   RR     RR   CC
SSSSSS  HH    HH   AA    AA   RR     RR   CCCCCC
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STRATEGIC HIGH ALTITUDE RADIANCE CODE

VERSION 1.0

********** CO NIGHT WINTER 45-LATITUDE SECOND RUN WITH NEW LOS **********

Sat Feb 4 14:30:15 1989

INPUTS USED TO GENERATE NUMBER DENSITIES

DATE GENERATED:	Sat Feb 4 12:57:41 1989
POPULATION FILE NAME:	CO45WIN.DAT
ATMOSPHERE USED:	SAT45WN.DAT
NUMBER OF LAYERS:	60
EXOATMOSPHERIC TEMPERATURE(K):	1500.0
DAY-NIGHT PARAMETER:	NIGHT
NEMESIS PARAMETERS:	
TOTAL NUMBER OF PHOTONS:	10000
MAXIMUM ORDER OF SCATTERING:	200
SUNSHINE PARAMETER:	0
EARTHSHINE PARAMETER:	1
MOLECULES IN POPULATION FILE:	
	CO

TRANSITION		FREQUENCY(CM-1)	RADIANCE
CO(1)	-CO(0)	2143.272	Y
CO(2)	-CO(0)	4260.063	Y
CO(2)	-CO(1)	2116.791	Y

LINE-OF-SIGHT GEOMETRY INFORMATION

PATH SELECTION: LIMB VIEWING
TANGENT HEIGHT(KM): 150.00

SEGMENT	LOWER ALT.(KM)	UPPER ALT.(KM)	SEGMENT LENGTH(KM)	COLUMN DENSITIES(MOLEC/CM2) CO
1	290.00	300.00	48.21	.3793E+12
2	280.00	290.00	49.91	.4852E+12
3	270.00	280.00	51.81	.6242E+12
4	260.00	270.00	53.96	.8086E+12
5	250.00	260.00	56.41	.1055E+13
6	240.00	250.00	59.24	.1401E+13
7	230.00	240.00	62.57	.1896E+13
8	220.00	230.00	66.54	.2611E+13
9	210.00	220.00	71.41	.3678E+13
10	200.00	210.00	77.56	.5313E+13
11	190.00	200.00	85.69	.7963E+13
12	180.00	190.00	97.15	.1258E+14
13	170.00	180.00	115.11	.2148E+14
14	160.00	170.00	149.84	.4214E+14
15	150.00	160.00	722.55	.3259E+15
16	160.00	170.00	149.84	.4214E+14
17	170.00	180.00	115.11	.2148E+14
18	180.00	190.00	97.15	.1258E+14
19	190.00	200.00	85.69	.7963E+13
20	200.00	210.00	77.56	.5313E+13
21	210.00	220.00	71.41	.3678E+13
22	220.00	230.00	66.54	.2610E+13
23	230.00	240.00	62.57	.1896E+13
24	240.00	250.00	59.24	.1401E+13
25	250.00	260.00	56.41	.1055E+13
26	260.00	270.00	53.96	.8086E+12
27	270.00	280.00	51.81	.6242E+12
28	280.00	290.00	49.91	.4852E+12
29	290.00	300.00	48.21	.3793E+12

29 LAYERS TOTAL PATH LENGTH: 2813.40

BAND RADIANCE SUMMARY

TRANSITION		FREQUENCY(CM-1)	NO. OF LINES		BAND RADIANCE
			TOTAL	RELAYERED	(W/SR/CM2)
CO(1)	-CO(0)	2143.272	79	79	.53604E-09
CO(2)	-CO(0)	4260.063	64	64	.11637E-11
CO(2)	-CO(1)	2116.791	45	45	.29587E-10
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TOTAL			188	188	.56679E-09

*U.S. GOVERNMENT PRINTING OFFICE: 1989-600-000/00031