OLD DOMINION UNIVERSITY RESEARCH FOUNDATION

DEPARTMENT OF GEOPHYSICAL SCIENCES
SCHOOL OF SCIENCES AND HEALTH PROFESSIONS
OLD DOMINION UNIVERSITY
NORFOLK, VIRGINIA

Technical Report GSTR-81-7

DATA REDUCTION ANALYSIS AND APPLICATION TECHNIQUE DEVELOPMENT FOR ATMOSPHERIC TRACE GAS CONSTITUENTS DERIVED FROM REMOTE SENSORS ON SATELLITE OR AIRBORNE PLATFORMS

By

Joseph C. Casas
and
Shirley A. Campbell

Principal Investigator: Earl C. Kindle

Final Report
For the period ending June 30, 1980

Prepared for the
National Aeronautics and Space Administration
Langley Research Center
Hampton, Virginia

Under
Research Grant NSG-1395
Sherwin M. Beck, Technical Monitor
Atmospheric Environmental Science Division

(NASA-CR-164478) DATA REDUCTION ANALYSIS AND APPLICATION TECHNIQUE DEVELOPMENT FOR ATMOSPHERIC TRACE GAS CONSTITUENTS DERIVED FROM REMOTE SENSORS ON SATELLITE OR AIRBORNE PLATFORMS Final (Old Dominion Univ.,

N81-26594

Unclas
G3/45 26630

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Submitted by the
Old Dominion University Research Foundation
P.O. Box 6369
Norfolk, Virginia 23508

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DATA REDUCTION ANALYSIS AND APPLICATION TECHNIQUE DEVELOPMENT FOR ATMOSPHERIC TRACE GAS CONSTITUENTS DERIVED FROM REMOTE SENSORS ON SATELLITE OR AIRBORNE PLATFORMS

By

Joseph C. Casas[1] and Shirley A. Campbell[2]

INTRODUCTION

This report summarizes work performed under NASA Grant No. NSG-1395. Research efforts concentrated on four comprehensive program areas:

(1) development of a STAR-100 version of a radiative transfer model similar to the SMART program,

(2) support of the St. Petersburg flight test of MAPS brassboard instrument,

(3) support for the summer MONEX program, and

(4) investigative studies for the implementation of the MAPS experiment to the OSTA-1 payload for Space Shuttle.

The primary objective of this project was to investigate the applicability of the gas filter correlation radiometer (GFCR) to the measurement of tropospheric carbon monoxide gas from airborne and earth-orbiting platforms. To this end research has focused on the operational application of the GFCR technique to the remote measurement of CO from low-altitude aircraft platforms.

An assessment of the GFCR measurement system to a regional measurement program was conducted through extensive aircraft flight testing of several versions of the GFCR. This test program was conducted by personnel at NASA/Langley Research Center (LaRC) and complemented by an Old Dominion University (ODU) comprehensive research program. This research program

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involved investigative work in the areas of flight-test planning and coordination, acquisition of verifying CO measurements, determination and acquisition of supporting meteorological data requirements, and development of supporting computational software.

NOMENCLATURE

c_i	concentration of absorbing gas, ppm
C8	Boltzmann distribution constant, cm Kelvin
E	monochromatic upwelling radiance, W $cm^{-2}sr^{-1}$
E'	energy of the lower state, cm^{-1}
f	Chapman function, dimensionless
h	sensor altitude index, dimensionless
h'	uppermost layer altitude index, dimensionless
H_s	wavenumber-dependent sun irradiance at the top of the atmosphere, W $cm^{-1}sr^{-2}cm^{-1}$
k	atmospheric layer index, dimensionless
l	thickness of layer, cm
m	constant, 1.5 for water vapor and 1.0 for all other molecules, dimensionless
N^0	Planck blackbody radiation, W $cm^{-2}sr^{-1}$
p	mean pressure of layer, atm (1 atm = 1.01325 E+5 N/m^2)
p_e	equivalent pressure, atm
S_{in}	adjusted spectral line intensity, $atm^{-1}cm^{-2}$
S_0	spectral line intensity, $atm^{-1}cm^{-2}$
T	layer temperature, Kelvin
T_0	reference temperature corresponding to spectral line parameters, Kelvin
T_s	surface temperature, Kelvin
z	altitude index, dimensionless

α_{in}	adjusted spectral line halfwidth, cm^{-1}
α_0	line halfwidth, cm^{-1}
β_{in}	Lorentz line shape, dimensionless
ε	wavenumber-dependent surface emittance, dimensionless
κ_{in}	wavenumber-dependent absorption coefficient, $atm^{-1}cm^{-1}$
τ	gaseous transmittance at a particular altitude, dimensionless
Θ	sun zenith angle, degrees
ω	wavenumber (inverse wavelength), cm^{-1}
$\bar{\omega}$	averaged wavenumber, cm^{-1}

Subscripts:

i	gas species number
n	spectral line number

STAR-100

Introduction

The use in recent years of high-sensitivity and high effective spectral resolution (less than 0.1 cm^{-1}) instrumentation, such as MAPS, in the remote measurement of trace atmospheric gases has required refinements in the computational methods used in calculating the atmospheric transmittance in the infrared spectral region. The principal techniques of detecting trace atmospheric gases, specifically gaseous pollutants, have been described by Ludwig (ref. 1). The success of these techniques not only depends upon the ability of the instrument technique to discriminate between the pollutant and interfering spectral lines, but also requires an accurate knowledge of high-resolution pollutant and atmospheric spectra. This can be accomplished by applying a line-by-line atmospheric radiative transfer program.

The program presented in this report is an improved version of the line-by-line program written by Casas and Campbell and described in reference 2. The program was written for a vector processing machine, the

STAR-100, in a language (SL/1) specifically designed to take advantage of its parallel processor capabilities. The objective was to develop an efficient, generalized, line-by-line, atmospheric radiative transfer program, which would be readily adapted to many different infrared sensor research needs. This report describes the program, the analytical concepts upon which it is based, as well as the STAR-100 computer and the SL/1 programming language.

The STAR-100 (ref. 3) is a large-scale, high-speed digital computer employing parallel processing and a virtual memory. These features permit fast matrix-oriented calculations with practically unlimited storage capacity. The STAR-100 is a vector machine: i.e., the optimum performance of the computer occurs with contiguous floating point operands defined by a location and length. It achieves a high performance level through use of a parallel processor that causes the elements of vectors to be fetched and buffered to a segmented arithmetic unit. This segmentation is analogous to an assembly line operation in that some elements of the vector will have completed processing at the same time that other elements are still undergoing the same processing. The effect is that all elements of the vector appear to have completed processing in parallel, hence the term "parallel processor." The STAR has been shown to achieve a performance improvement over a CDC 6600 of 60 to 1 using vector operations.

The virtual memory system of the STAR-100 gives the illusion that physical memory is much larger than it actually is. The portion of the user's program not residing in physical memory is written on a disk in the form of 512 or 65,536 64-bit word blocks called pages. When a portion of a program residing on the disk is needed in main memory, the page containing the needed information is moved into main memory and the unneeded page is moved out to the disk. Thus, program efficiency is improved by structuring code to limit the number of pages moving in and out of memory. For a more detailed explanation of paging concepts, see reference 4.

SL/1 (ref. 5) is a programming language developed at NASA/LaRC and designed specifically for the STAR-100 computer. The vector type instructions facilitate the high performance level of the computer. The language also has the capability of using 32-bit (halfword) or 64-bit (fullword) operands. The 32-bit vector will process in half the time of a 64-bit vector, but has 32 bits less precision per word. The compiler for SL/1 executes on a CDC 6400 at NASA/LaRC; thus a program can be compiled and edited on a conventional sequential computer before transmission to the STAR for execution, resulting in a cost- and time-saving feature. In the event of an error, the SL/1 language provides convenient diagnostics for debugging. This a a time-saving and beneficial feature for the programmer. Thus, SL/1 was chosen for the program presented in this report because of the 32-bit vector capability, the ability to compile on the CDC 6400, the error-processing features, and the availability of clear and well-structured language concepts. The algorithms used and their translation to SL/1 are described in the following sections.

Software Methodology

A line-by-line radiative transfer computer program was needed to efficiently perform the task of data reduction for infrared pollutant sensors being developed by NASA/LaRC. The Simulated Monochromatic Atmospheric Radiative Transfer version 2 (SMART2) program was written to reduce data-reduction cost by using the vector-processing capabilities of the STAR-100 computer and the beneficial features of the SL/1 programming language. This required a restructuring of the conventional algorithms used for line-by-line programs on sequential computers in order to conform to vector type operations. The modular structure of the program was designed to permit modifications of the computational algorithms without affecting the program framework. In addition, thorough documentation was necessary for program clarity.

To minimize computation time without a loss in accuracy, certain assumptions were made concerning the atmosphere and radiative transfer processes. To compute the transmittance from the surface of the Earth to a sensor altitude, h, the modeled atmosphere between these points is divided into a number of homogeneous layers, i.e., regions within which the temperature, total pressure, and concentrations of the primary and interfering molecular absorbers are considered to be uniform. The error in this approximation may be made as small as desired by subdividing the atmosphere into a sufficiently large number of layers. The total radiance incident on a sensor at altitude h is given by

$$E(h) = \int_{\Delta\omega} E(\omega)d\omega \tag{1}$$

where $\Delta\omega$ is the spectral bandpass of interest and $E(\omega)$ is the total monochromatic upwelling radiance.

For a cloud-free, nonscattering atmosphere under local thermodynamic equilibrium, the atmospheric radiative transfer equation for the total monochromatic upwelling radiant energy, $E(\omega)$, seen by a nadir viewing type of sensor can be written as

$$\begin{aligned} E(\omega) = {} & \varepsilon(\omega)\ N^0(\omega,T_s)\ \tau(\omega,h) \\ & + \int_0^h N^0\left[\omega,T(z)\right] \frac{d(\omega,z)}{dz} \\ & + \frac{1}{\pi}\left[1 - \varepsilon(\omega)\right] \cdot (\cos\theta)\ H_s(\omega) \\ & \cdot \tau(\omega,h) \cdot \tau(\omega,h') \cdot f(\Theta) \end{aligned} \tag{2}$$

where $\varepsilon(\omega)$ is the wavenumber-dependent surface emittance and $N^0(\omega,T_s)$ is the Planck blackbody function which is dependent on wavenumber and surface temperature T_s or radiating gas temperature at a particular altitude $T(z)$. The monochromatic transmittance of the atmosphere between the emitting surface z and the altitude of the sensor h is represented by $\tau(\omega,h)$, and the monochromatic vertical transmission of the entire modeled atmosphere is represented by $\tau(\omega,h')$. The solar zenith angle is Θ and the wavenumber-dependent sun irradiance at the top of the atmosphere is H_s. The Chapman function $f(\Theta)$ (ref. 1), is equal to $\sec\Theta$ for $0^0 \leq \Theta \leq 60^0$ and is equal to the Chapman polynomial for $\Theta < 60^0$. The three terms on the right-hand side of equation (2) represent, respectively, the surface emission of the Earth, the atmospheric emission, and the solar reflected energy (see fig. 1). All of these components must be considered in the solar-thermal overlap region at 4.6 μm. These terms are represented in SMART2 by TOTSURF, SUMRAD, and RADSUN, respectively. Appendix A

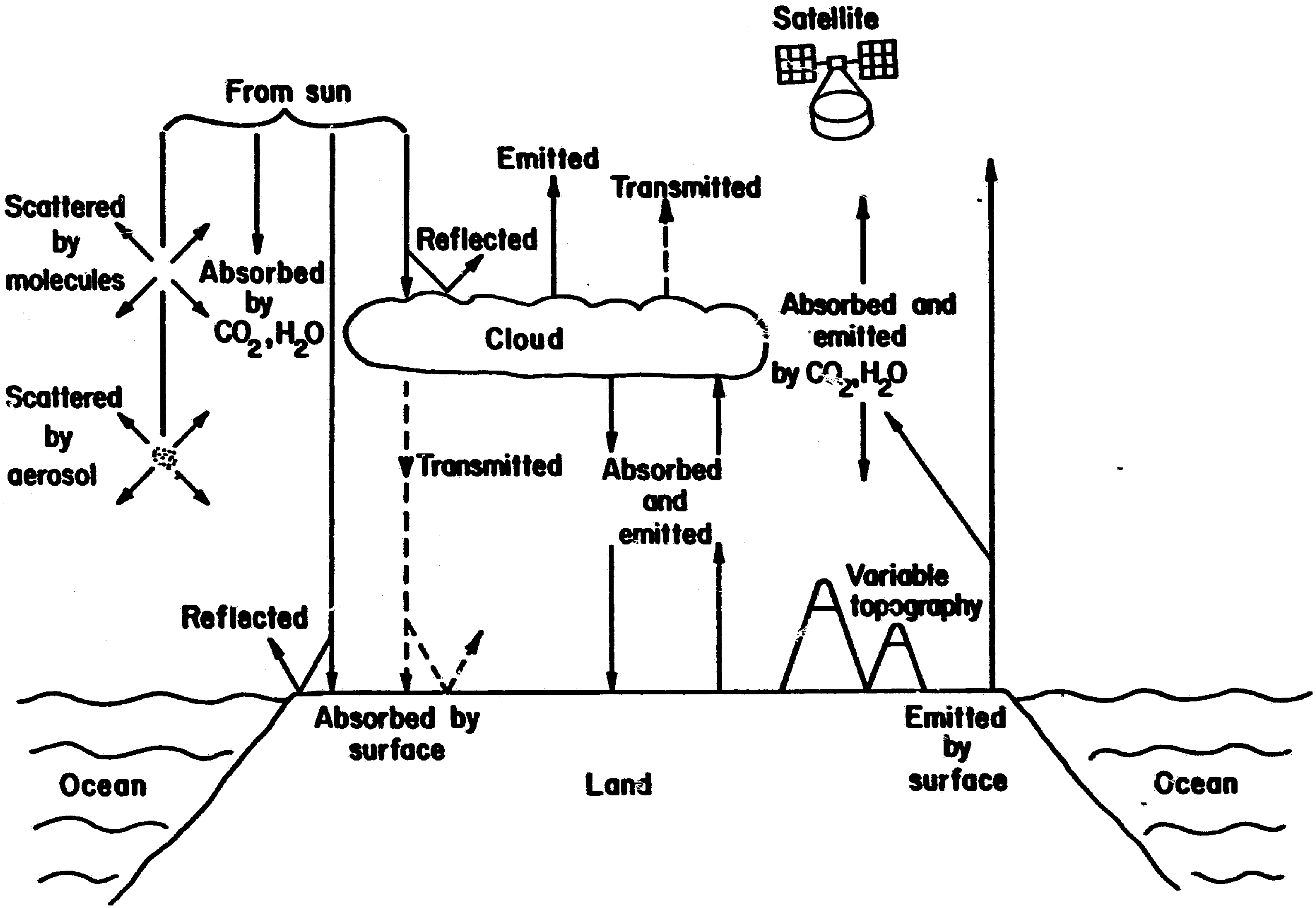

Figure 1. Interaction of radiation with the atmosphere.

contains a dictionary of SL/1 variables, and figure 2 is an overview of the SMART2 program structure.

A closer examination of the form of equations (1) and (2) indicates two very distinct differences between the methodology of SMART2 and conventional line-by-line radiative transfer programs. The first difference is the order in which the integrals over $\Delta\omega$ and over the change in altitude, Δh, are performed. By initially integrating over Δh monochromatically, the error associated with transmittance averaging is eliminated, i.e., the monochromatic transmission at any altitude h is given by

$$\tau(\omega,h) = \prod_{z=1}^{h} \tau(\omega,z) \tag{3}$$

and not by

$$\overline{\tau}(\Delta\omega,h) = \frac{1}{\Delta\omega} \sum_{z=1}^{h} \tau(\omega,z) \tag{4}$$

The spectral resolution of the transmittance values, i.e. the number of ωs at which the absorption coefficient is calculated, is defined by a constant stepping size, DW.

The second difference between SMART2 and most other line-by-line radiative transfer programs is the specification of the order of limits of integration over altitude. The lower limit of integration is the radiating source, and the upper limit is the sensor altitude which allows for practical computation of the monochromatic and total integrated transmission at the top of each atmospheric layer as seen by equation (3). This approach eliminates redundant calculations of atmospheric transmittance in evaluating signals from aircraft platform sensors at various altitudes.

Theoretically, the total absorption coefficient at any wavenumber ω consists of contributions from all spectral lines; however, for

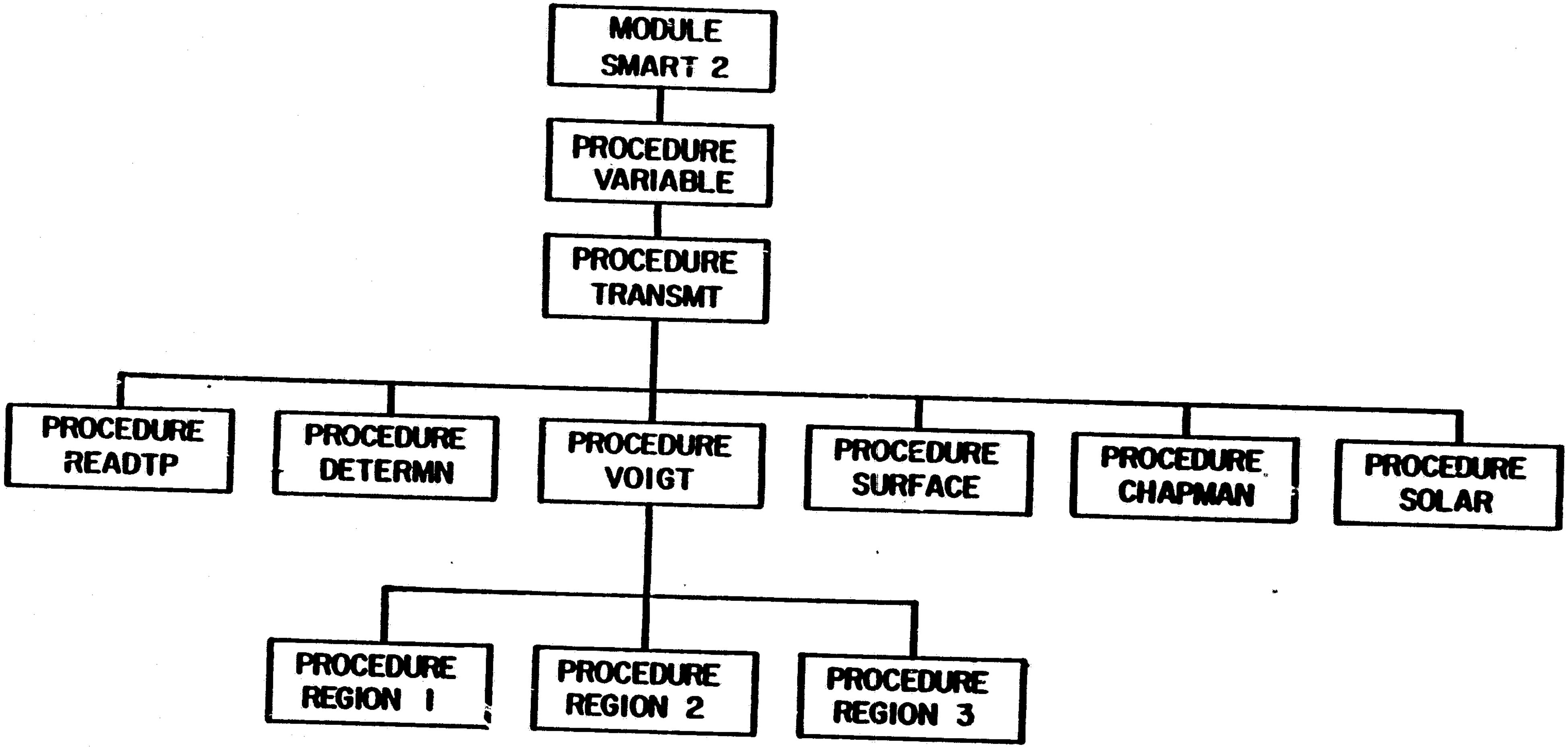

Figure 2. SMART2 program structure.

practical computational purposes, only lines within the vicinity of ω are considered for calculation in SMART2. The contribution to the absorption coefficient of lines in the vicinity of ω can be divided into two parts, direct and wing. Those lines within an interval defined by approximately 100 halfwidths of the primary gas to each side of ω are considered to be direct contributors to the absorption coefficient, while those lines lying outside of this interval result in wing absorption. In the SMART2 calculation of direct-line absorption contribution, the OMEGA vector contains center wavenumbers calculated with a constant DW stepping size. The spectral lines included for direct-line absorption contribution for all elements of the OMEGA vector are determined in procedure DETERMN by choosing those lines in the interval OMEGA|1|-CMINV to OMEGA|last| + CMINV. Thus, the vector-processing capability of STAR calculates absorption coefficients of all elements of the OMEGA vector concurrently with the same spectral lines (WAVEN). When new elements of OMEGA vector are calculated, a different WAVEN is computed. The size of the OMEGA vector is determined by the user. For atmospheric carbon monoxide using the Lorentzian line profile, a SMINV of 5 cm^{-1} was selected. This value is approximately 100 times the line halfwidth of CO. A 250 element size of the OMEGA vector is sufficiently large to take advantage of the vector processing of STAR, but does not affect the direct-line contribution assumption of a symmetric 5 cm^{-1} interval about the centerline. Presently, the SMART2 program does not include wing contribution.

The SMART2 program performs initialization of all variables required for the calculation of the monochromatic gas transmissions for center wavenumbers in the OMEGA vector (TAU) for each atmospheric layer. The algorithm for the computation of TAU is initiated by a call of the READTP procedure, which reads all spectral reference information into vectors, i.e. line position (OMEGSTR), halfwidth (ALPHA), intensity (SZ), lower energy level (EL), and species identification number (ILINE) from the spectral line parameter reference tape for the band interval WI - CMINV to WF + CMINV. READTP uses the Q30PNMAP library routine, which performs the implicit input by mapping the spectral line file into a COMMON block (ABLOCK). The individual vectors are initialized by equivalencing elements of the vectors to elements of the ABLOCK COMMON block. The McClatchey spectral line parameter tape (ref. 6) was used to obtain all spectral reference information. The parameters read should be under room temperature and standard pressure (296 K and 1 atm) conditions or the appropriate conversion must be performed prior to reading these parameters in procedure READTP (see Appendix B).

The gaseous transmittance at a particular altitude as a function of wavenumber is given by

$$\mathrm{TAU}(\omega) = \tau(\omega) = \exp\left[-\sum_i K_i(\omega) p c_i \ell\right] \tag{5}$$

where $K_i(\omega)$ is the wavenumber-dependent absorption coefficient of gas species i (their sum being ABSCOP), p (PRES) is the total mean pressure of layer k, c_i (GASCONC) is the concentration of absorbing gas i, and ℓ (THICK) is the thickness of the kth layer.

In general, the absorption coefficient of the nth line of species i is described by

$$K_{in}(\omega) = S_{in}\beta_{in}(\omega) \tag{6}$$

where S_{in} is the layer temperature (TEMP) corrected line intensity and β_{in} is the line shape function, i.e., Lorentz, Voigt, or Doppler. The Lorentz line shape is given by

$$\beta_{in}(\omega) = \frac{1}{\pi} \frac{\alpha_{in}}{\left(\omega - \omega_{in}\right)^2 + \left(\alpha_{in}\right)^2} \tag{7}$$

where α_{in} (ADJALPH) is the temperature- and pressure-dependent line half-width for layer k and is given by

$$\mathrm{ADJALPH} = \alpha_{in} = \alpha_0 p_e \left(\frac{T_0}{T}\right)^{1/2} \tag{8}$$

The calculation of ADJALPH is a vector operation and includes all spectral lines in the OMEGSTR vector. The reference line halfwidth, α_0 (ALPHA), is read from the spectral line parameter tape at temperature T_0 (REFTEMP). The equivalent pressure, p_e, is a function of the ratio of self-broadening to the nitrogen-broadening efficiency (BROAD), the total pressure (PRES), and the concentration of the absorbing gas (GASCONC) as given by

$$p_e = [\mathrm{GASCONC} * (\mathrm{BROAD} - 1) + 1] * \mathrm{PRES} \tag{9}$$

In the case of trace gases in the atmosphere, the equivalent pressure is set equal to the total atmospheric pressure since self-broadening is insignificant.

The line intensity (S) depends upon the temperature through the Boltzman distribution factor (ref. 7) and is expressed as

$$S_{in} = S_0\left(\frac{T_0}{T}\right)^m \exp\left\{\left[-\ C8\left(\frac{T_0}{T}\right) - 1\right] \cdot \frac{E'}{T_0}\right\} \tag{10}$$

or

$$S = \mathrm{SZ} * \mathrm{TCONSQ} * \mathrm{EXP}\ \left|-\mathrm{C8} * (\mathrm{TEMPCON} - 1) * \mathrm{EL/REFTEMP}\right| \tag{11}$$

where m is 1.5 for water vapor, methane, and ozone and 1.0 for other infrared active molecules, such as carbon monoxide, carbon dioxide, nitrous oxide, and C8 is the Boltzman distribution constant; S is calculated with a vector instruction in SMART2 and represents the line intensities for each spectral line in the OMEGSTR vector. The user has the option of calculating ABSCOF as determined by the Lorentz function, by the Doppler function, or by an approximation to the Voigt function detailed by Pierluissi (ref. 8) in procedure VOIGT. The line shape for each layer (IPROF) must be designated in the input and need not be the same for each layer.

The total absorption (ABSCOFT) at each wavenumber in the OMEGA vector is determined by the summation of the absorption coefficients for all lines within the interval. In addition, the user can automatically obtain the total absorption coefficient (ABST) that corresponds to a maximum of 10 different, primary gas, vertical mixing ratio profiles as defined by KMULT. Each value of KMULT is multiplied by the volume mixing ratio of the primary gas in every layer, resulting in a bias shifting of the input vertical mixing ratio profile. ABST is calculated as the sum of two components, ABSCOF(1), which is the absorption coefficient for the primary gas, and ABSCOFT, which is the absorption coefficient for all other interfering gases. The absorption effects of continua, such as nitrogen and water vapor, could be easily considered in the form of an added third term to ABST after the necessary algorithms for accurately calculating the continuum absorption in the spectral region under consideration have been developed.

After completion of the monochromatic calculation of ABST at all wavenumbers in the OMEGA vector, the transmittance is calculated as a vector instruction shown by equation (5). This procedure is repeated for the whole band, resulting in a TAU value for each layer k. The self-emission (RADATM) of each layer is then calculated as a vector instruction via the wavenumber-dependent energy described by the Planck blackbody function. The temperature used in the Planck function is the mean temperature (TEMP) of the emitting layer. The emissivity (EMISS) of the layer is determined by the calculated transmittance of that layer as given by

$$\mathrm{EMISS} = 1 - \mathrm{TAU} \tag{12}$$

The total monochromatic transmittance (ATMTAU) at the top of each atmospheric layer is then calculated as a vector instruction by

$$\mathrm{ATMTAU}(\omega) = \Pi_k \ \mathrm{TAU}_k(\omega) \tag{13}$$

The next operation performed by SMART2 is the determination of the new center wavenumbers to be placed in the OMEGA vector for the purpose of repeating the transmittance calculations for the entire spectral band being considered, i.e., WI - CMINV to WF + CMINV. The size of the wavenumber increment used in absorption coefficient calculations is arbitrary and depends upon the spectral resolution required by the user, since the absorption coefficient varies rapidly as a function of relative position to the spectral line centers. For applications of SMART2 to carbon monoxide under tropospheric pressures, a constant stepping size (DW) of 0.01 cm^{-1} was determined to most efficiently describe the wavenumber-dependent absorption coefficient. The transmittance calculation for a new OMEGA vector is performed and the corresponding results, i.e., ATMTAU(ω) and RADATM(ω), are calculated and summed. This procedure is repeated until ATMTAU and RADATM for the entire spectral band are calculated.

A program option allows the calculation of the monochromatic emission of the Earth (TOTSURF) as a function of one or more surface temperatures and emissivities. This option employs procedure SURFACE in the calculation of the wavenumber-dependent Planck distribution of energy as a vector operation. Another option to the program, the solar contribution (RADSUN), is calculated as a vector operation in accordance with equation (2) by procedure SOLAR, where the Chapman function calculated in procedure CHAPMAN is employed in determining the slant path transmittance of incident solar radiation. The solar contribution is a function of one or more solar zenith angles and surface emissivities. The three terms of equation (2), i.e., TOTSURF, SUMRAD, and RADSUN, are then obtained by attenuating each component by the appropriate atmospheric transmittance (ATMTAU) value for an altitude corresponding to the top of each atmospheric layer. For convenience, the trapezoidal rule is used for integration of all variables over the spectral band being examined. Computed results are then printed out. A complete program listing and brief description of each of the program sections are contained in Appendix C.

Operating Instructions

The input from cards contains the atmospheric, surface, and solar parameters used by SMART2. The physical setup for the PRES, TEMP, THICK, and IPROF data is arranged such that the atmospheric layers are read in ascending order of altitude (descending order of pressure). The GASCONC data follow in the same order with the concentrations of the gases in each layer placed in the 10-column field corresponding to the identification number of the gas, i.e., water vapor (ID = 1) concentration in columns 1 to 10 and carbon dioxide (ID = 2) in columns 11 to 20.

To avoid unnecessary calculations, one should exercise care in choosing the values of DW and CMINV. For our sample case using carbon monoxide as the primary gas, 2080 to 2170 cm^{-1} as the band width, DW of 0.01 cm^{-1}, and CMINV of 5 cm^{-1}, 90,000 points of integration were considered with 1,557 spectral lines included from the tape. If DW were chosen smaller and/or CMINV were chosen larger, these totals would be greater, causing execution time to increase.

The size of the OMEGA vector is determined by the LITERALLY declaration of NINC in MODULE SMART2. Since the STAR is a vector-processing machine, use of vector lengths greater than 100 is recommended. The vector size should be sufficiently large to take advantage of the machine's hardware, but should not affect the 5 cm^{-1} assumption on the direct contribution interval about the centerline. The optimum size of OMEGA was determined to be 250.

Caution should be exercised concerning the units of the line parameters read from the spectral line tape. These units must be as specified in the dictionary of SL/1 variables, and the reference temperature of the spectral lines must be 296.0 K or the appropriate change to REFTEMP in the program must be performed. A sample case input is listed in Appendix D.

Presently, one may choose either Lorentzian, Doppler, or Pierluissi's approximation to the Voigt profile in the calculation of spectral line shape. The Voigt profile requires a significant increase in the calculation time.

The IOPT parameter allows the user to choose which components of the equation of radiative transfer [eq. (2)] will be calculated. An IOPT of 1 will calculate only the atmospheric portion for 1 atmospheric profile, up to 10 concentrations of the primary gas using the XMULT vector, and up to 9 different interferents. An IOPT of 2 will calculate the atmospheric contribution and the Earth surface emission for one or more surface temperatures (or surface emissivities). An IOPT of 3 will calculate the atmospheric and surface contributions in addition to the solar reflected energy for one or more solar zenith angles and surface emissivities.

The program is currently set up to perform carbon monoxide calculations in the 4.6-μm spectral band. Any other primary pollutant gas may be considered by setting the values of IPOLLUT and IDENT(1) to the identification number of that species and by making necessary adjustments to spectral band widths. The gas-broadening coefficient, BROAD, must be changed to correspond to the gas being considered.

The trapezoidal rule is used as the integration approximation. Should the user wish to incorporate a different integration process, the trapezoidal rule may be easily replaced.

The program output consists of the band-integrated average transmission and total upwelling radiance as a function of altitude and primary gas concentration. In addition, the band-integrated total surface radiance is listed as a function of altitude, surface temperature, surface emissivity, and primary gas concentration. The band-integrated total solar radiance is printed as a function of altitude, solar zenith angle, surface emissivity, and primary gas concentration. A sample case output is listed in Appendix E.

The input listed in Appendix D and output in Appendix E correspond to a problem of determining the atmospheric, surface, and solar radiance calculated at the top of each of the 15 modeled atmospheric layers. The model chosen is a midlatitude summer atmosphere with a corresponding water vapor profile (ref. 9). The sun zenith angles are 45° and 75°. The pollutant is carbon monoxide, calculated at 10 different concentrations in each layer, with interferent constituent concentrations of water vapor and carbon dioxide held constant in each layer. The spectral band is 4.6 μm.

Comparisons and Conclusions

Any computer program is only as accurate as the theoretical model on which it is based and the numerical algorithms coded into program instructions. As outlined previously under "Software Methodology," the accuracy of this model is dictated by the assumptions made in our application to a specific problem.

To verify the results of the SMART2 calculated absorption coefficients, a comparison was made to an existing program written by Casas and Campbell (ref. 2). This program has been tested and verified with analytical calculations of absorption and laboratory spectra. The comparison was made on the basis of computation time and accuracy. For a 15-layer atmospheric model including carbon monoxide, water vapor, and carbon dioxide, for a 90 cm^{-1} band interval, at a constant stepping size of 0.01 cm^{-1}, using 2 surface temperatures, 2 surface emissivities, and 2 solar zenith angles, assuming a Lorentzian profile in each layer, the total processing time was 2898.79 sec on a Cyber 173. On the STAR-100, the processing time was based upon the size of the OMEGA vector. The optimum vector size was determined by comparing four test cases using vector sizes of 250, 500, 1000, and 2250 for the atmospheric contribution only. The processing times were (a) 250 vector size - 16.58 sec, (b) 500 vector size - 16.08 sec, (c) 1000 vector size - 14.61 sec, and (d) 2250 vector size - 13.89 sec. A comparison was made between the band-integrated average transmission of the Casas and Campbell program and the SMART2 program with the four vector lengths. The results are shown in tables 1 and 2. Thus, a vector size of 250 is the most accurate. Using this vector size, the same test case run on the Cyber 173 was run on the STAR-100, resulting in an execution time of 29.2 sec. This is a factor of 99 improvement over the Cyber 173.

The processing times for 11 test cases using the same 15 layer atmosphere run on the STAR computer are listed below. Although a vector length of 250 has been shown to be the most accurate, a vector length of 1000 was used for these test cases to save time and cost.

SL/1 has an optimizing parameter (OPT) associated with the compiler that is used to optimize code. The higher the optimization parameter, the more efficient the code. The test cases run for vector lengths of 100 are listed in table 2. Thus, the Voigt profile takes significantly more execution time than the Lorentz. The surface contribution adds an insignificant amount of time, while the solar calculation adds about 2 sec per case.

A line-by-line radiative transfer program for the STAR-100 computer has been developed and described. Any of the specific task procedures may be easily substituted by algorithms that are more suitable and convenient to the user.

The program currently performs carbon monoxide calculations in the fundamental 4.6-μm spectral band. By making necessary adjustments,

Table 1. Percentage difference between band-integrated average transmission of SMART2 program and Casas and Campbell program.

Vector Size	Layer	Concentration of CO (ppm)		
		0.0	0.2	1.0
250	1	0.081	0.088	0.099
	5	0.206	0.229	0.300
	10	0.221	0.255	0.364
	15	0.221	0.258	0.384
500	1	0.123	0.131	0.151
	5	0.322	0.352	0.453
	10	0.348	0.394	0.555
	15	0.349	0.399	0.587
1000	1	0.185	0.196	0.224
	5	0.492	0.537	0.683
	10	0.533	0.601	0.835
	15	0.534	0.609	0.878
2250	1	0.231	0.245	0.286
	5	0.621	0.679	0.880
	10	0.673	0.763	1.086
	15	0.674	0.776	1.144

Table 2. Execution times for 11 test cases run on the STAR-100.

Test Case	Time (sec)
1. Atmospheric contribution only, all layers using Lorentz profile	
a. OPT = 1	14.61
b. OPT = 2	12.48
c. OPT = 3	12.46
2. Atmospheric contribution only, Doppler profile used in layers 14 and 15	
a. OPT = 1	20.62
3. Atmospheric contribution only, all layers using Voigt profile	
a. OPT = 1	119.10
b. OPT = 2	118.89
4. Atmospheric contribution, surface contribution with 2 surface temperatures and 2 emissivities, all layers using Lorentz profile	
a. OPT = 1	14.74
b. OPT = 2	12.79
5. Atmospheric contribution, surface contribution with 2 surface temperatures and 2 emissivities, solar contribution with 2 solar zenith angles, all layers using Lorentz profile	
a. OPT = 1	24.28
b. OPT = 2	21.80
6. Atmospheric contribution, surface contribution with 2 surface temperatures and 2 emissivities, solar contribution with 2 solar zenith angles, all layers using Voigt profile	
a. OPT = 2	131.75

other gas species transmittance calculations may be made. Future additions to the program will include a sub-Lorentzian wing absorption algorithm, the water vapor and nitrogen continuum absorption algorithms, and a routine to plot transmittance as a function of wavenumber.

The storage required for the program is not applicable to the STAR-100 computer. For our sample case, 15 layers required 29.2 sec of execution time. By utilizing the vector capability of the STAR computer, program efficiency increased, and a cost savings factor of seven was realized.

ST. PETERSBURG FLIGHT TEST

During the period of August 13 to August 20, 1979, a series of flight tests of the MAPS (Measurement of Air Pollution from Satellite) brassboard sensor system test evaluations was performed in the St. Petersburg, Florida area. The purpose of this series of flight tests was to provide a data base for the evaluation of the response of the carbon monoxide channels of the sensor system to (1) hot and humid subtropical atmospheric conditions, (2) partial cloud cover in the IFOV of the sensor, and (3) land/water interface changes.

The urban area of St. Petersburg-Clearwater provided a relatively isolated site from industrial carbon monoxide emission. The largest production of CC in this area results from automobile traffic. An estimate of the emissions was obtained by correlating traffic counter data with EPA automobile emission rates.

The remote sensor system and supporting equipment were flown onboard a Cessna 402B twin-engine aircraft modified with a nadir viewing port. The aircraft was equipped with dual 360 channel navcoms, DME, ADF, and a Loran navigation system. The aircraft experimental hardware included (1) remote carbon monoxide sensor, (2) radiation thermometer (11.6 μm), (3) hygrometer system, (4) total air temperature probe, (5) altitude pressure transducer, (6) LORAN route verification system, (7) data acquisition system, (8) 35-mm aerial camera, and (9) LORAN navigation system.

The test was comprised of one primary test area and three secondary test areas. The primary area was the St. Petersburg-Clearwater peninsula as shown in figure 3. Test flights at an altitude of 6.1 km (20,000 ft) and 2.4 km (8,000 ft) were flown during the test period. An extensive report of the results of these tests is forthcoming. In general, the flight test was a success and an excellent data base was obtained. A work task involving a MAPS commitment to be flown on the Space Shuttle delayed the reduction and analysis of the data from the St. Petersburg flight; however, a complete analysis of it will be performed prior to December 1981.

SUMMER MONEX EXPERIMENT

The Summer Monsoon Experiment (MONEX) was conducted over the Indian Ocean from May to August 1979 in conjunction with the second Special Observing Period of the Global Weather Experiment. The MONEX observations provided an unprecedented data set for a basic study of the monsoon phenomenon. The Asian monsoons, due to their dimension and intensity, represent the largest disturbance of general circulation, creating strong cross-equatorial flows and hemispheric interactions. During this test period the MAPS remote sensor was operational in over 20 test flights. The purpose of this research was to examine the interhemispheric exchange of CO during the monsoon.

ODU personnel performed research in two primary areas supporting NASA/LaRC work. The first area of research support was in the operation of a gas chromatographic system which obtained CO and CH_4 concentration profiles from the CV990 aircraft during the test period. A very large data base was obtained. As collaborative scientists, ODU personnel performed research tasks in the planning of the test, new software development and testing of a new inflight data reduction algorithm. Specific tasks performed involved extensive analysis of meteorological data and radiometer data obtained from the MAPS remote sensor system. High altitude (12-km) remote sensor data was obtained for the first time. An extensive data set was acquired during the Saudi Arabia Experiment and Arabian Sea Experiment phase of the Summer MONEX program.

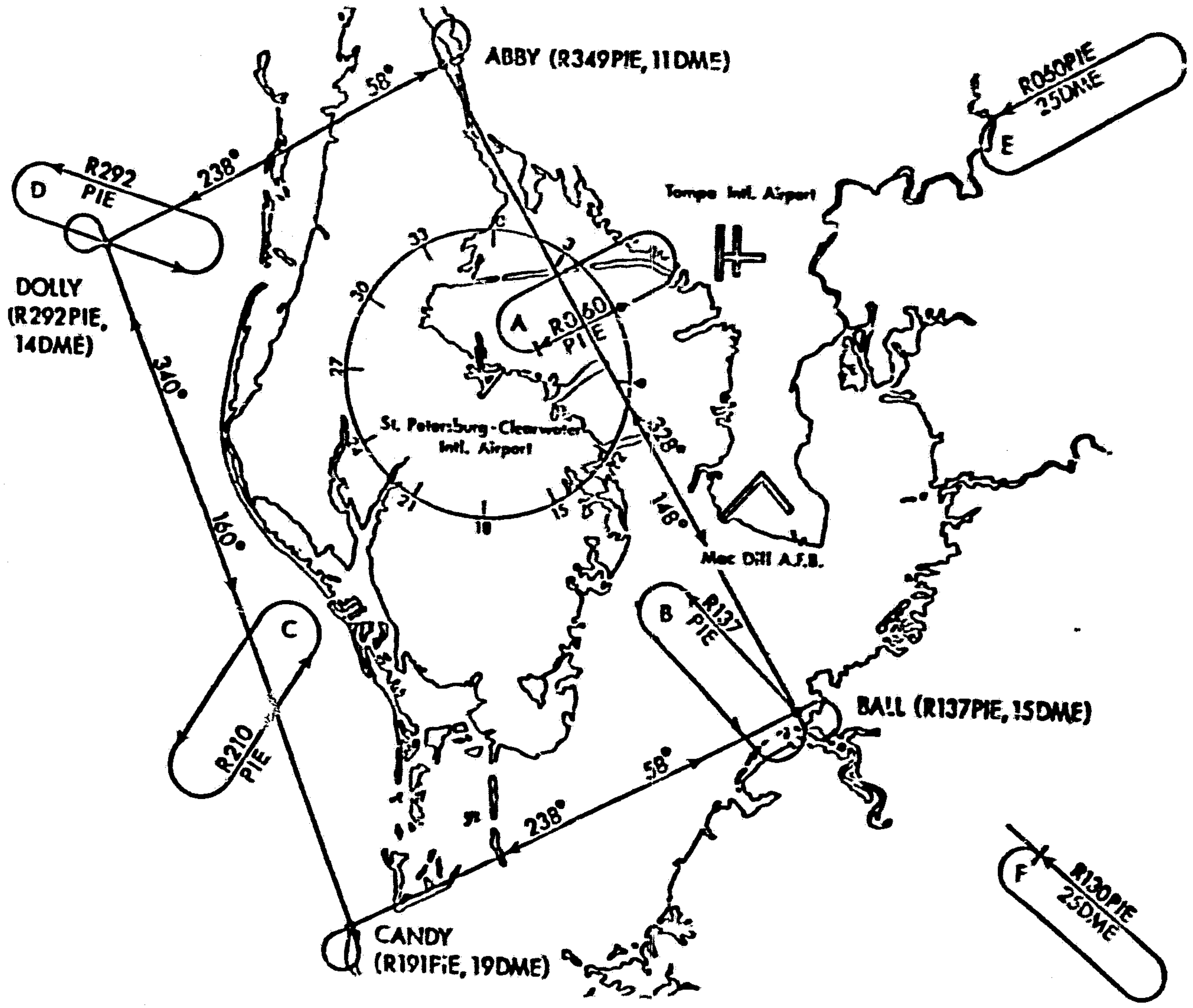

Figure 3. Primary test area.

A comprehensive analysis of the entire data set and publication of the results will be completed by October 1981.

OSTA-1 PAYLOAD

Investigative studies were implemented for the development of a MAPS experiment for the OSTA-1 payload for Space Shuttle. Comprehensive parametric studies were utilized in the preliminary design and development of this space platform version of the MAPS remote sensor system.

These theoretical studies were required to determine operational limitations for a MAPS global remote sensor CO measurement experiment. The implementation of the MAPS experiment to a space platform involved many multifaceted fundamental research studies and involved many man hours. Specific areas of work were optimization of instrument gas cell pressures and determination of (1) instrument signal sensitivity to atmospheric temperature profiles changes, (2) instrument signal sensitivity to surface temperature characteristics, (3) gas filter correlation instrument signal function, and (4) calibration requirements.

APPENDIX A

DICTIONARY OF SL/1 VARIABLES

MDOULE SMART2

A	number of integration points
AA	length of wavenumber interval, cm^{-1}
ABSCOF(NS,NL)|NINC|	monochromatic absorption coefficients
ABSCOFT|NINC|	monochromatic total absorption coefficient for all interfering gaseous constituents
ABST|NINC|	monochromatic total absorption coefficient for all gaseous constituents
ADJALPH|NLIN|	adjusted halfwidths for all spectral lines considered
ALPHA|NLIN|	halfwidth values at half maximum for all spectral lines considered
ALPHD|NLIN|	halfwidth values at half maximum for all Doppler spectral lines considered
ATMTAU(NX)|NINN|	calculated monochromatic transmission of the atmosphere at the top of the atmospheric layer
BB|NLIN|	bit vector used to find the nonlinear molecular species for rotational partition function calculation
BD|NINC|	bit vector used to determine if REGION1 of Voigt profile should be used
BE|NINC|	bit vector used to determine if REGION2 of Voigt profile should be used
BF|NINC|	bit vector used to determine if REGION3 of Voigt profile should be used
BRADX	primary gas pressure broadening coefficient
BRDFAC	primary gas pressure broadening factor
BROAD	short form of BRADX
C7	first radiation constant (1.1908E-12 W cm^{-2} $sr^{-1}cm^{-1}$)

C8	Boltzmann's constant (1.439 cm K)
CHAP NZ	exponential component of the Chapman transmission function of the atmosphere for all solar zenith angles
CM2	2 * CMINV
CMINV	minimum distance above and below OMEGA considered as centerline absorption in the transmittance calculation
COEF|9|	coefficients of eighth degree polynominal used in Chapman function
COMPABS|NINC|	line profile component of absorption coefficient
CONC|NS|	concentration of gases used for transmittance calculations
D1	0.
D2	1.
DIFSUN|41|	vector of differences between succeeding elements of SUNFLUX vector
DIFW|41|	vector of differences between succeeding elements of SUNW vector
DUMMY(NL)|NLIN|	dummy vector used for intermediate calculations
DUMMY1(NL)|NLIN|	dummy vector used for intermediate calculations
DW	integrating wavenumber increment, cm^{-1}
DW1	32-bit form of DW
LE|NLIN|	energy of lower state of transition of OMEGSTR from spectral line parameter tape, cm^{-1}
EMISS|NEM|	32-bit form of EMISX
EMISX|NEM|	thermal emissivities of the surface of the Earth
FIRST	the position of the first spectral line to be included for centerline absorption relative to the OMEGSTR vector
GASCONC(NL)|16|	32-bit form of GASCONX

GASCONX(NL) 16	concentration of gases used for transmittance calculations, ppm
I	do loop index
IDENT|10|	vector of identification numbers corresponding to gas species identification numbers from spectral line parameter tape
IDENTN|NIT|	vector of gas species identification numbers for spectral lines to be included in center-line absorption
ILINE|NLIN|	vector of gas species identification numbers of OMEGSTR from spectral line parameter tape
IOPT	option parameter 1 - atmospheric contribution only 2 - atmospheric and surface contributions 3 - atmospheric, surface, and solar contributions
IPOLLUT	primary gas species identification number
IPROF|NL|	line profile option parameter 1 - Lorentz 2 - Voigt 3 - Doppler
IUPPER	number of integration points calculated
J	do loop index
K	do loop index
L	do loop index
LOWER	lowest wavenumber in OMEGSTR vector
M	do loop index
MCCLAT|12800|	vector of spectral line information placed on Q30PNMAP file
MOLWT|NLIN|	molecular weights of gas species corresponding to OMEGSTR vector
MWT|12|	molecular weights of gas species corresponding to gas species identification number
NEM	number of surface emissivities used for dimension purposes

NEMIS	number of actual surface emissivities considered
NINC	number of OMEGAs considered for transmittance calculation at a time
NIT	maximum number of wavenumbers considered for centerline absorption calculation used for dimension
NL	number of atmospheric layers used for dimension purposes
NLAY	number of actual atmospheric layers considered
NLIN	number of spectral lines from tape used for dimension purposes
NOMEG	number of actual spectral lines from tape considered
NS	number of gas species used for dimension purposes
NSG	number of surface temperatures used for dimension purposes
NSPEC	number of actual gas species considered
NSURF	number of actual surface temperatures considered
NUMN	number of actual wavenumbers considered for centerline absorption calculation
NX	number of primary gas concentration multipliers used for dimension purposes
NXM	number of actual primary gas concentration multipliers considered
NZ	number of solar zenith angles used for dimension purposes
NZEN	number of actual solar zenith angles considered
OMEGA|NINC|	vector of center wavenumbers of the sub-intervals being considered for transmittance calculations
OMEGSTR|NLIN|	vector of wavenumbers read from spectral line parameter tape

OPATH|NL|	optical path of atmospheric layers, atm-cm
P|NINC|	vector of $\vert\omega-\omega_0\vert$
PLANCK|NINC|	thermal emission of the surface
PRES|NL|	32-bit form of PREX
PREX|NL|	pressure of atmospheric layers, atm
PROFAC1(NL)|NLIN|	multiplicative variable for line profile
PROFAC2|NINC|	multiplicative variable for line profile $(\vert\omega-\omega_0\vert/\alpha)$
RADATM(NX)|NINC|	the radiation upwelling from the atmosphere as a result of atmospheric gaseous molecular emission
RADSUN|NX|	SUMSUN integrated
REFTEMP	reference temperature of spectral line parameters from tape
ROOTEMP|NL|	square root of layer temperature
S(NL)|NLIN|	adjusted line strength of spectral lines from tape
SUMRAD(NL)|NX|	RADATM integrated
SUMSUN(NL,NZ,NEM)|NX|	radiation upwelling from the atmosphere as a result of incident solar energy
SUMSURF(NL,NSF,NEM)|NX|	radiation upwelling from the atmosphere as a result of Earth surface emission
SUMTAU(NL)|NX|	ATMTAU integrated
SUN|NINC|	interpolated solar flux values for OMEGA considered
SUNCOM(NEM)|NZ|	wavenumber-independent portion of solar contribution
SUNFLUX|41|	wavenumber-dependent solar energy incident at the top of the atmosphere
SUNW|41|	wavenumbers corresponding to SUNFLUX
SURFCOM|NINC|	component of surface energy contribution
SZ|NLIN|	line strength values from spectral line parameter tape, atm^{-1}cm^{-2}

TAU|NINC|	transmission of an atmospheric layer
TAUSLAT(NX,NZ)|NINC|	total atmospheric slant path coefficient
TCONSQ(NL)|NLIN|	temperature dependence of the rotational partition function
TEMP|NL|	32-bit form of TEMX
TEMPCON(NL)|NLIN|	temperature adjustment for line halfwidth
TEMX|NL|	temperature of atmospheric layer, Kelvin
THETA|NZ|	solar zenith angles
THICK|NL|	32-bit form of THICX
THICX|NL|	thickness of atmospheric layer, cm
TINV|NL|	inverse of layer temperature
TOTSUN|NINC|	radiation upwelling from the atmosphere as a result of incident solar energy
TOTSURF|NX|	SUMSURF integrated
TRAN(NX,NL)|NINC|	vector used to save atmospheric transmission values
TSURF|NSF|	32-bit form of TSURX
TSURX|NSF|	surface temperatures to be considered
UPPER	highest wavenumber in OMEGSTR vector
W1	the first wavenumber of the OMEGA vector
W3|NINC|	OMEGA cubed
WAVEN|NIT|	vector of wavenumbers to be included in centerline absorption
WF	final wavenumber used for transmittance calculation
WI	initial wavenumber used for transmittance calculation
X|NINC|	Voigt absorption coefficient parameter
XMULT|NX|	32-bit form of XMULX
XMULX|NX|	primary gas concentration multipliers

Y NINC	Voigt absorption coefficient parameter

PROCEDURE READTP

IERR	error parameter for Q30PNMAP

PROCEDURE DETERMN

BA	bit vector used to determine the lines to be included in the interval about the center wavenumber for transmittance calculation
IJ	do loop index
OMEG1	first wavenumber in the interval about the center wavenumber
OMEG2	final wavenumber in the interval about the center wavenumber

PROCEDURE REGION1

AN|30|	Voigt profile coefficients
C1, S1, S3, T, T3, X1, XSER, Y1, YSER|NINC|	Voigt profile parameters
LL	do loop index
N, NCOUNT	Voigt profile parameters
PISQ, X2, XN, YNEW, Y2, YN, YNEW	Voigt profile parameters

PROCEDURE REGION2

A1, A2, A3, A4, A5, A6	Voigt profile parameters
C1, F, G, H, R, S1, S3, T, T3, X1, X2, Y1, Y2|NINC|	Voigt profile parameters

PROCEDURE REGION 3

B1, B2, B3, B4	Voigt profile parameters
C1, F, G, R, S1, S3, T, T3, X1, Y1|NINC|	Voigt profile parameters

APPENDIX B

UNIT CONVERSION

In the past, various units have been used to define the line intensities; therefore, the following conversion factors may be helpful.

At standard temperature and pressure condition, STP,

$$1\ (\text{cm-atm})_{STP} = 2.69 \times 10^{19}\ \text{molecules/cm}^2;$$

however, at some temperature T',

$$1\ (\text{cm-atm})_{T'} = \frac{273.15\ \text{K}}{T'\ \text{K}} \times 2.69 \times 10^{19}\ \text{molecules/cm}^2$$

APPENDIX C

PROGRAM LISTING

Module SMART2

SMART2, the program executive, defines the global declarations. The LITERALLY declaration associates an identifier with a sequence of characters. The INITIAL declaration initializes variables prior to execution.

```
MODULE SMART2 BEGIN VARIABLE;
/* THIS SIMULATED NONCHROMATIC ATMOSPHERIC RADIATIVE TRANSFER
    (SMART) PROGRAM CALCULATES THE TOTAL UPWELLING INFRARED RADIATION
    THROUGH A MODELED ATMOSPHERE BY EVALUATING THE ONE-DIMENSIONAL
    EQUATION OF RADIATIVE TRANSFER */
$OPT=2;
$NOCHECK;
   EXTERNAL PROCEDURE(INTEGER,BIT VECTOR(64),REAL,INTEGER)@30PNMAP;
   REAL VECTOR (12000) NCCLAT;
   LITERALLY "1560" NLIN;   /* NUMBER OF LINES READ IN */
   LITERALLY "500" NIT;  /* MAXIMUM NUMBER OF LINES TO BE INCLUDED IN
                            AN INTEGRATION INTERVAL */
   LITERALLY "15" NL;  /* NUMBER OF ATMOSPHERIC LAYERS */
   LITERALLY "250" NINC;   /* NUMBER OF WAVENUMBERS CONSIDERED FOR
                                 CALCULATION AT A TIME */
   LITERALLY "3" NS;   /* NUMBER OF GAS SPECIES CONSIDERED */
   LITERALLY "10" NX;  /* NUMBER OF MULTIPLIERS */
   LITERALLY "2" NSF;  /* NUMBER OF SURFACE TEMPERATURES */
   LITERALLY "2" NEM;  /* NUMBER OF SURFACE EMISSIVITIES */
   LITERALLY "2" NZ;   /* NUMBER OF SOLAR ZENITH ANGLES */
   SHORT REAL VECTOR (NLIN) ARRAY(NL) TEMPCON,TCONSQ,DUMMY1,DUMMY,
    ADJALPH,S,PROFAC1,ALPHG;
   SHORT REAL VECTOR (NLIN) WNEGSTR,ALPHA,SZ,EL,MOLWT;
   INTEGER VECTOR (NLIN) ILINE;
   INTEGER VECTOR (NL) IPROF;
   INTEGER VECTOR (10) IDENT;
   REAL VECTOR (NX) XMULX;
   SHORT REAL VECTOR (NX) AMULT,TOTSURF,RADSUM;
   SHORT REAL VECTOR (NL) TEMP,PRES,THICK,UPATH,TINV,ROOTEMP;
   REAL VECTOR (NL) TEMX,PREX,THICX;
   SHORT REAL VECTOR (NIT) WAVSM;
   INTEGER VECTOR (NIT) IDENTN;
   SHORT REAL VECTOR (NINC) OMEGA,PLANCK,ABSCOFT,PROFAC2,COMPABS,TAU,
    ABST,P,W3,X,Y,SUM,TOTSUM,SURFCON;
   BIT VECTOR (NINC) BD,BE,BF;
   REAL VECTOR (16) ARRAY(NL) GASCONX;
   SHORT REAL VECTOR (16) ARRAY(NL) GASCONC;
   SHORT REAL VECTOR (NX) ARRAY(NL) SUNRAD,SUNTAU;
   SHORT REAL VECTOR (NINC) ARRAY(NX) RADATM,ATMTAU;
   SHORT REAL VECTOR (NINC) ARRAY(NX,NL) TRAN;
   BIT VECTOR (NLIN) BB;
   SHORT REAL VECTOR (NINC) ARRAY(NS,NL) ABSCOF;
```

```
SHORT REAL VECTOR (NS) CONC;
REAL VECTOR (12) MWT;
SHORT REAL VECTOR (NZ) ARRAY(NL,NSF,NCM) SUNSURF;
SHORT REAL VECTOR (NSF) TSURF;
REAL VECTOR (NSF) TSURX;
SHORT REAL VECTOR (NEM) EMISS;
REAL VECTOR (NEM) EMISX;
SHORT REAL VECTOR (NZ) ARRAY(NL,NZ,NEM) SUNSUM;
SHORT REAL VECTOR (NINC) ARRAY(NZ,NZ) TAUSLAT;
SHORT REAL VECTOR (41) SUNW,SUNFLUX,DIFSUM,DIFW;
REAL VECTOR (9) COEF;
REAL VECTOR (NZ) THETA;
SHORT REAL VECTOR (NZ) CHAP;
SHORT REAL VECTOR (NZ) ARRAY(NEM) SUNCUM;
SHORT REAL BROAD,BRDFAC,REFTEMP,C6,DB1,C7,AA,D1,D2;
REAL WI,WF,CMINV,A,BRADX,DW,LOWER,UPPER,W1,CM2;
INTEGER NLAY,KMP,NSPEC,IPOLLUT,I,J,K,NUMEG,NUMN,IUPPER,L,
 FIRST,IOPT,M,NSURF,NEMIS,NZEN;
COMMON ABLOCK(NCCLAT);
COMMON BBLOCK(TEMPCON,ICONSQ,DUMMY1,DUMMY,ADJALPH,S,PROFAC1,ALPHW);
COMMON CBLOCK(OMEGSTO,ALPHA,SZ,EL,NOLUT,ILINE);
COMMON DBLOCK(OMEGA,PLANCK,ABSCOFT,PROFAC2,COMPABS,TAU,ABST,P,W3,X,
           Y);
COMMON EBLOCK(SUNRAD,SUNTAU,RADATM,ATMTAU);
INITIAL(MWT=\18.015,44.01,47.998,44.013,28.01,16.0429,31.00,46.063,
           30.01,36.46,17.03,63.01\);
INITIAL(SUNW=\1961.75,1980.20,2020.20,2061.00,2105.26,2150.34,
            2197.80,2247.19,2298.85,2352.94,2409.64,2469.14,
            2531.64,2597.40,2666.67,2739.73,2816.90,2898.55,
            2985.07,3076.92,3174.60,3278.69,3389.83,3508.77,
            3636.36,3773.58,3921.57,4081.63,4255.32,4444.44,
            4651.16,4878.05,5128.21,5405.41,5714.29,6060.61,
            6451.61,6896.55,7407.41,8000.00,8695.65\);
INITIAL(SUNFLUX=\.274E-6,.284E-6,.296E-6,.307E-6,.323E-6,.338E-6,
               .343E-6,.359E-6,.362E-6,.371E-6,.411E-6,.439E-6,
               .462E-6,.481E-6,.501E-6,.526E-6,.554E-6,.580E-6,
               .607E-6,.639E-6,.673E-6,.708E-6,.748E-6,.789E-6,
               .835E-6,.883E-6,.938E-6,.995E-6,1.058E-6,1.128E-6,
               1.204E-6,1.288E-6,1.378E-6,1.474E-6,1.581E-6,
               1.697E-6,1.826E-6,1.964E-6,2.110E-6,2.258E-6,
               2.322E-6\);
INITIAL(COEF=\-8.39732633E-13,2.12740023E-10,-9.45994657E-9,
            -1.37253304E-6,3.80591534E-5,2.30546152E-2,
            -2.44211946,9.78869273E+1,-1.41635206E+3\);
```

Procedure VARIABLE

VARIABLE is a procedure subordinate to SMART2. VARIABLE initializes variables to appropriate values.

```
PROCEDURE VARIABLE;
/* INITIALIZE VARIABLES TO ZERO */
   FOR I:= 1 TO NL DO
    TEMPCON[I]:= 0.;
    TCONSO[I]:= 0.;
    DUMMY1[I]:= 0.;
    DUMMY[I]:= 0.;
    ADJALPH[I]:= 0.;
    S[I]:= 0.;
    PROFAC1[I]:= 0.;
    ALPHO[I]:= 0.;
   END;
   OMEGSTR:= 0.;  ALPHA:= 0.;  SZ:= 0.;  CL:= 0.;  MOLWT:= 0.;
   ILINE:= 0; IDENT:= 0;
   OMEGA:= 0.; PLANCK:= 0.; ABSCOFT:= 0.; PWGFAC2:= 0.; COMPABS:= 0.;
   TAU:= 0.; ABST:= 0.; F:= 0.; W3:= 0.; X:= 0.; Y:= 0.;
   FOR J:= 1 TO NL DO
    SUMRAD[J]:= 0.;
    SUMTAU[J]:= 0.;
   END;
   FOR I:= 1 TO NX DO
    RADATM[I]:= 0.;
    ATMTAU[I]:= 0.;
   END;
   FOR I:= 1 TO NL DO
    FOR J:= 1 TO NSF DO
     FOR K:= 1 TO NEM DO
      SUMSURF[I,J,K]:= 0.
     END;
    END;
    FOR J:= 1 TO NZ DO
     FOR K:= 1 TO NEM DO
      SUMSUN[I,J,K]:= 0.;
     END;
    END;
   END;
   BB:= FALSE;
   C0:=1.439;
   C7:= 1.1906E-12;
   D1:= 0.;
   D2:= 1.;
   CALL TRANSMT;
END;
```

Procedure TRANSMT

TRANSMT is a procedure called by VARIABLE. TRANSMT performs the following:

(1) Reads the atmospheric profile information by calling READTP;

(2) Calculates the temperature- and pressure-dependent line half-width and the line intensity for all spectral lines;

(3) Determines the wavenumbers at which the absorption coefficient is calculated using a constant stepping size;

(4) Chooses the spectral lines included in the direct line absorption contribution by calling DETERMN;

(5) Calculates absorption coefficients using either the Lorentz, Doppler, or Pierluissi's approximation to the Voigt profile;

(6) Calculates atmospheric transmittance and radiance as a function of altitude and primary gas concentration;

(7) Includes surface monochromatic emission as a function of one or more surface temperatures and emissivities; and

(8) Calculates solar contribution as a function of one or more solar zenith angles and surface emissivities.

Functions (7) and (8) are program options.

```
PROCEDURE TRANSMT;
/* READ INPUT FROM CARDS
     NLAY= NUMBER OF ATMOSPHERIC LAYERS
     NXM= NUMBER OF MULTIPLIERS FOR PRIMARY GAS (MAX=10)
     NSPEC= NUMBER OF GASES TO BE CONSIDERED--PRIMARY + INTERFERENTS
      (MAX=10)
     IOPT= OPTION PARAMETER
        1--ATMOSPHERIC ONLY
        2--ATMOSPHERIC + SURFACE
        3--ATMOSPHERIC + SURFACE + SOLAR
     IDENT= ARRAY OF IDENTIFICATION NUMBERS FOR GAS SPECIES TO BE
      CONSIDERED (MAX=NSPEC) PRIMARY POLLUTANT SHOULD BE FIRST */
   READ(NLAY,NXM,NSPEC,IOPT) '4I5';
   READ(IDENT[1:NSPEC]) '10I5';
/*   WI= INITIAL WAVENUMBER
     WF= FINAL WAVENUMBER
     DW= WAVENUMBER INCREMENT FOR INTEGRATION
     CHINV= DISTANCE ABOVE AND BELOW THE CENTER WAVENUMBER CONSIDERED FOR
      LINE ABSORPTION IN THE TRANSMITTANCE CALCULATION
     IPOLLUT= IDENTIFICATION NUMBER OF PRIMARY POLLUTANT
     BROAD= PRIMARY GAS PRESSURE BROADENING COEFFICIENT */
   READ(WI,WF,DW,CHINV,IPOLLUT,BRADX) '4F10.4,I5,F10.4';
   BROAD:= CONTRACT(BRADX);
/*   XMULT= ARRAY OF MULTIPLIERS TO BE USED FOR PRIMARY GAS.  THESE
      NUMBERS ARE MULTIPLIED BY THE BACKGROUND CONCENTRATION OF THE
      PRIMARY GAS TO GIVE UP TO 10 DIFFERENT CONCENTRATIONS FOR THIS
      GAS. */
   READ(XMULX[1:NXM]) '8F10.4';
   XMULT:= CONTRACT(XMULX);
/*   TEMP= TEMPERATURE OF LAYER IN KELVIN
     PRES= PRESSURE OF LAYER IN ATMOSPHERES
     THICK= LAYER THICKNESS IN CM
     IPROF= LINE PROFILE TO BE USED
        1--LORENTZ
        2--VOIGT
        3--DOPPLER */
   FOR I:= 1 TO NLAY DO
    READ(PREX[I],TEMX[I],THICX[I],IPROF[I]) '3F10.4,I5';
   END;
```

```
    TEMP:= CONTRACT(TEMX);
    PRES:= CONTRACT(PREX);
    THICK:= CONTRACT(THICX);
/* GASCONC= CONCENTRATION OF THE IDENT GASES IN EACH LAYER-- CONCENTRATION
     MUST BE READ CORRESPONDING TO THE IDENTIFICATION NUMBER */
    FOR I:= 1 TO NLAY DO
     READ(GASCONX(I)) #8E10.3#;
     GASCONC(I):= CONTRACT(GASCONX(I));
    END;
/* NSURF= NUMBER OF SURFACE TEMPERATURES
    NEMIS= NUMBER OF SURFACE EMISSIVITIES
    TSURF= ARRAY OF SURFACE TEMPERATURES
    EMISS= ARRAY OF SURFACE EMISSIVITIES */
    IF (IOPT=2) .OR. (IOPT=3) THEN
     READ(NSURF,NEMIS) #2I5#;
     READ(TSURX(1:NSURF)) #8F10.4#;
     READ(EMISX(1:NEMIS)) #8F10.4#;
     TSURF:= CONTRACT(TSURX);
     EMISS:= CONTRACT(EMISX);
    END;
/* NZEN= NUMBER OF SOLAR ZENITH ANGLES
    THETA= ARRAY OF SOLAR ZENITH ANGLES */
    IF IOPT = 3 THEN
     READ(NZEN) #I5#;
     READ(THETA(1:NZEN)) #6F10.4#;
    END;
/* PRELIMINARY CALCULATIONS INCLUDE
      OPATH= OPTICAL PATH OF EACH LAYER
      TINV= INVERSE OF LAYER TEMPERATURE
      ROOTEMP= SQUARE ROOT OF LAYER TEMPERATURE
      REFTEMP= REFERENCE TEMPERATURE CORRESPONDING TO IDENTIFICATION
       NUMBERS OF SPECTRAL LINE PARAMETERS FROM TAPE */
    OPATH:= PRES * THICK;
    TINV(1:NLAY):= 1./TEMP(1:NLAY);
    ROOTEMP:= SQRT(TEMP);
    REFTEMP:= 296.;
/* ADJUST THE LAYER PRESSURE FOR PRIMARY GAS BROADENING COEFFICIENT */
    FOR I:= 1 TO NLAY DO
     BRDFAC:= (BROAD-1.) * GASCONC(I)(IPOLLUT) + 1.;
     PRES(I):= PRES(I) * BRDFAC;
    END;
/* IF THE SOLAR COMPONENT IS INCLUDED, CALCULATE THE CHAPMAN FUNCTION
```

```
    AND THE WAVENUMBER-INDEPENDENT PART OF THE SOLAR CONTRIBUTION */
   IF IOPT = 3 THEN
    CALL CHAPMAN;
    FOR I:= 1 TO NEMIS DO
     SUNCOM[I]:= CONTRACT(COS(THETA/57.2957795)*(1.-EMISX[I]));
    ENDE;
    DIFSUN:= ADJDIFF(SUNFLUX);
    DIFW:= ADJDIFF(SUNW);
   ENDI;
/* READ SPECTRAL LINE FILE FOR ALL LINES INCLUDED IN WI-CMINV TO
    WF*CMINV */
   CALL READTP;
/* PRINT THE ATMOSPHERIC PARAMETERS */
   PRINT $1H1,'ATMOSPHERIC PARAMETERS'$;
   PRINT $' THE KEY FOR THE GAS SPECIES IS:'/5X,'1---H2O'/5X,'2---CO2'
    /5X,'3---O3'/5X,'4---N2O'/5X,'5---CO'/5X,'6---CH4'/5X,'7---O2'/
    5X,'8---SO2'/5X,'9---NO'/5X,'10--HCL'/5X,'11--NH3'/5X,'12--HNO3'$;
   PRINT(IDENT[1:NSPEC])
   $' LAYER  PRES (ATM)  TEMP (K)      THICK (CM)    PATH (ATM-CM)',2X,
    5(I6,6X)$;
   FOR K:= 1 TO NLAY DO
    FOR L:= 1 TO NSPEC DO
     CONC[L]:= GASCONC[K][IDENT[L]];
    ENDE;
    PRINT(K,PRES[K],TEMP[K],THICK[K],OPATH[K],CONC[1:NSPEC])
     $1H ,I2,6X,F6.4,5X,F7.2,5X,1PE12.5,2X,E12.5,4X,5(E10.3,2X)$;
   ENDE;
   PRINT(IPOLLUT) $1H0,'THE INVESTIGATED POLLUTANT IS ',I5$;
   PRINT(WI,WF) $1H ,'THE WAVENUMBER INTERVAL IS ',F10.2,' TO ',F10.2$;
   CM2:= 2*CMINV;
   PRINT(CM2) $1H ,'THE MINIMUM SUBINTERVAL OF INTEGRATION IS ',F10.2,
    ' CM-1'$;
   PRINT(DW) $1H ,'THE INTEGRATING INCREMENT IS ',F7.4,' CM-1'$;
   A:= (WF-WI)/DW;
   DW1:= CONTRACT(DW);
   IUPPER:= CEIL(A);
   PRINT(IUPPER) $1H ,'THE NUMBER OF INTEGRATION POINTS IS ',I10$;
/* FIND THE NON-LINEAR MOLECULAR SPECIES (H2O,CH4,O3) IN ORDER TO
    CALCULATE THE ROTATIONAL PARTITION FUNCTION */
   BB:= (ILINE = 1) .OR. (ILINE = 3) .OR. (ILINE = 6);
/* MAKE NECESSARY TEMPERATURE AND PRESSURE ADJUSTMENTS TO CALCULATE
    S/(PI*ALPHA) WHICH IS STORED IN THE PROFACI ARRAY */
```

```
   FOR I:= 1 TO NLAY DO
    TEMPCON(I):= REFTEMP * TINV(I);
    TCONSQ(I):= TEMPCON(I) * TEMPCON(I);
    DUMMY1(I):= SQRT(TEMPCON(I));
    DUMMY(I):= TCONSQ(I) * DUMMY1(I);
    (TCONSQ(I),BB):= DUMMY(I);
    ADJALPH(I):= ALPHA * PRES(I) * DUMMY1(I);
    DUMMY(I):= -1. * C0 * (TEMPCON(I) - 1.) * EL/REFTEMP;
    S(I):= EXP(DUMMY(I)) * SZ * TCONSQ(I);
    PROFAC1(I)[1:NOMEG]:= .3183 * S(I)[1:NOMEG]/ADJALPH(I)[1:NOMEG];
/* USE VOIGT OR DOPPLER PROFILE WHERE DESIRED */
    IF (IPROF(I) = 2) .OR. (IPROF(I) = 3) THEN
     ALPHD(I)[1:NOMEG]:= 3.5810E-7 * OMEGSTR[1:NOMEG] * SQRT(TEMP(I)/
      MOLWT[1:NOMEG]);
     PROFAC1(I)[1:NOMEG]:= 4.6972E-1 * S(I)[1:NOMEG]/ALPHD(I)[1:NOMEG];
    ENDI;
   ENDF;
/* CALCULATE THE ABSORPTION COEFFICIENT MONOCHROMATICALLY.  THE CENTER
    WAVENUMBER IS CALCULATED BY A CONSTANT STEPPING SIZE.
     IUPPER= THE NUMBER OF WAVENUMBERS CONSIDERED
     OMEGA = THE CENTER WAVENUMBER */
   W1:= W1;
   FOR I:= 1 BY NINC TO IUPPER DO
    OMEGA:= CONTRACT(IOTA(W1,DW,NINC));
/* FOR EACH CENTER WAVENUMBER, THE LINES TO BE INCLUDED FOR
    TRANSMITTANCE CALCULATION MUST BE DETERMINED */
    CALL DETERMN(OMEGA[1],OMEGA[NINC]);
    FOR L:= 1 TO NS DO
     FOR K:= 1 TO NL DO
      ABSCOF(L,K):= 0.;
     ENDF;
    ENDF;
/* CALCULATE THE LINE PROFILE COMPONENT OF THE ABSORPTION
    COEFFICIENT AND PLACE IN THE COMPABS ARRAY */
    FOR K:= 1 TO NUMN DO
     FOR J:= 1 TO NLAY DO
      IF J = 1 THEN P:= ABS(OMEGA - WAVEN(K)); ENDI;
/* USE THE LORENTZ PROFILE IF DESIRED */
      IF IPROF(J) = 1 THEN
       PROFAC2:= P/ADJALPH(J)[FIRST + K-1];
       COMPABS:= PROFAC1(J)[FIRST+K-1]/(1.+PROFAC2 * PROFAC2);
      ENDI;
```

```
/* USE THE VOIGT PROFILE IF DESIRED */
     IF IPROF[J] = 2 THEN CALL VOIGT;
      COMPABS:= COMPABS * PROFAC1[J][FIRST+K-1] ENDI;
/* USE THE DOPPLER PROFILE IF DESIRED */
     IF IPROF[J] = 3 THEN
      PROFAC2:= P/ALPHD[J][FIRST+K-1];
      COMPABS:= PROFAC1[J][FIRST+K-1]*EXP(-6.9315E-1*PROFAC2*PROFAC2);
     ENDI;
     COMPABS:= COMPABS * GASCONC[J][IDENTN[K]];
/* SET UP THE ABSORPTION COEFFICIENT ARRAYS (ABSCOF) SUCH THAT ABSCOF(1)
    CORRESPONDS TO THE PRIMARY POLLUTANT AND THE REST OF ABSCUF
    CORRESPONDS TO THE REMAINDER OF THE IDENT ARRAY */
      FOR L:= 1 TO NSPEC DO
       IF IDENTN[K] = IDENT[L] THEN ABSCUF(L,J):= ABSCOF(L,J)+COMPABS;
       ENDI;
      ENDE;
    ENDE;
   ENDE;
/* CALCULATE THE TOTAL ATMOSPHERIC EMISSION (RADATM) AND TRANSMISSION
    (ATMTAU) THROUGH ALL OF THE ATMOSPHERIC LAYERS.  ABSCOFT IS THE
    TOTAL ABSORPTION COEFFICIENT FOR THE INTERFERING GASES AND ABST
    IS THE ABSORPTION COEFFICIENT FOR ALL OF THE GASES */
    W3:= C7 * OMEGA * OMEGA * OMEGA;
    FOR J:= 1 TO NLAY DO
     PLANCK:= W3/(EXP(C8*OMEGA/TEMP[J])-1.);
     ABSCOFT:= 0.;
     IF NSPEC > 1 THEN
      FOR L:= 2 TO NSPEC DO
       ABSCOFT:= ABSCOFT + ABSCOF(L,J);
      ENDE;
     ENDI;
     FOR K:= 1 TO NXM DO
      ABST:= ABSCOF(1,J) * XMULT[K] + ABSCOFT;
      TAU:= EXP(-1. * ABST * OPATH[J]);
      IF J = 1 THEN
       RADATM[K]:= 0.;
       ATMTAU[K]:= 1.;
      ENDI;
      RADATM[K]:= RADATM[K]*TAU + PLANCK * (1.-TAU);
      ATMTAU[K]:= ATMTAU[K] * TAU;
/* SUM THE ATMOSPHERIC EMISSION AND PLACE IN THE SUMRAD ARRAY.
   SUM THE ATMOSPHERIC TRANSMISSION AND PLACE IN THE SUMTAU ARRAY */
```

```
     SUMRAD(J)[K]:= SUMRAD(J)[K] + SUM(RADATM(K));
     SUMTAU(J)[K]:= SUMTAU(J)[K] + SUM(ATMTAU(K));
/* CALCULATE THE SURFACE COMPONENT IF DESIRED */
     IF (IOPT=2) .OR. (IOPT=3) THEN CALL SURFACE
     ENDI;
/* IF SOLAR COMPONENT IS DESIRED, THEN STORE ATMOSPHERIC TRANSMISSIONS
   AND CALCULATE SLANT PATH TRANSMISSION (TAUSLAT) */
     IF IOPT = 3 THEN TRAN(K,J):= ATMTAU(K) ENDI;
     IF (IOPT = 3) .AND. (J = NLAY) THEN
      BE:= ATMTAU(K) = 0.;
      (ATMTAU(K),BE):= D2;
      FOR L:= 1 TO NZEN DO
       TAUSLAT(K,L):= EXP(CHAP(L)*LN(ATMTAU(K)));
       (TAUSLAT(K,L),BE):= D1;
      ENDE;
      (ATMTAU(K),BE):= D1;
     ENDI;
    ENDE;
   ENDE;
/* CALCULATE THE SUN COMPONENT IF DESIRED */
   IF IOPT = 3 THEN CALL SOLAR ENDI;
  W1:= W1 + DW * NINC;
  ENDE;
  AA:= CONTRACT(WF-WI);
/* PRINT THE OUTPUT FOR EACH LAYER */
  FOR J:= 1 TO NLAY DO
   PRINT(J) #1H1,'LAYER ',I4#;
   IF IPROF(J) = 1 THEN PRINT#' THE LINE PROFILE IS LORENTZ'# ENDI;
   IF IPROF(J) = 2 THEN PRINT#' THE LINE PROFILE IS VOIGT'# ENDI;
   IF IPROF(J) = 3 THEN PRINT#' THE LINE PROFILE IS DOPPLER'# ENDI;
   PRINT(XMULT[1:NXM]) #' MULT    = ',1P10E12.4#;
   SUMRAD(J):= SUMRAD(J) * DW1;
   SUMTAU(J):= (SUMTAU(J) *DW1)/AA;
   PRINT(SUMTAU(J)[1:NXM],SUMRAD(J)[1:NXM]) #' ATMTAU = ',10F12.5/,
    ' ATMRAD = ',1P10E12.4//#;
   IF (IOPT=2) .OR. (IOPT=3) THEN
    FOR M:= 1 TO NEMIS DO
     FOR L:= 1 TO NSURF DO
      PRINT(EMISS(M)) #1H ,'SURFACE EMISSIVITY = ',F10.4#;
      PRINT(TSURF(L)) #1H ,' SURFACE TEMPERATURE = ',F10.4#;
      TOTSURF:= SUMSURF(J,L,M) * DW1;
      PRINT(TOTSURF[1:NXM]) #1H ,'   SURF= ',1P10E12.4/#;
```

```
      ENDF;
     ENDF;
    ENDI;
    IF IOPT = 3 THEN
     PRINT@1H /;
     FOR K:= 1 TO NZEN DO
      FOR L:= 1 TO NEMIS DO
       RADSUN:= SUMSUM(J,K,L) * DW;
       PRINT(THETA(K)) @1H ,'SOLAR ZENITH ANGLE = ',F6.2,' DEGREES'/;
       PRINT(EMISS(L)) @1H ,' SURFACE EMISSIVITY = ',F10.4/;
       PRINT(RADSUN(1:NXM)) @1H ,'    SUN = ',1P10E12.4/;
      ENDF;
     ENDF;
    ENDI;
   ENDF;
ENDP;
```

Procedure READTP

READTP is called by TRANSMT. READTP reads the spectral line parameter file for all lines from WI - CMINV to WF + CMINV. The Q30PNMAP library routine performs implicit input by mapping the spectral line file into the ABLOCK COMMON block. The individual vector elements are initialized by equivalencing to elements of the ABLOCK COMMON block.

```
PROCEDURE READTP;
/* READ SPECTRAL LINE PARAMETER FILE FOR ALL LINES FROM WI-
    WF*CMINV.  VARIABLES INCLUDE LINE LOCATION (OMEGSTR), H
     (ALPHA), LINE STRENGTH (SZ), GROUND STATE ENERGY (EL),
     IDENTIFICATION NUMBER (ILINE) */
    INTEGER IERR;
    CALL G3OPNMAP(IERR,X\434F424420202020\,MCCLAT[1],25);
    LOWER := WI-CMINV;
    UPPER := WF*CMINV;
    NOMEG := 0;
    PRINT #' MCCLATCHEY LINE PARAMETERS'#;
    PRINT #' THE KEY FOR THE GAS SPECIES IS:'/5X,'1---H2O'/5X,'2
     /5X,'3---O3'/5X,'4---N2O'/5X,'5---CO'/5X,'6---CH4'/5X,'7---
     5X,'8---SO2'/5X,'9---NO'/5X,'10--HCL'/5X,'11--NH3'/5X,'12--0
    PRINT #' WAVENUMBER  ALPHA  LINE STRENGTH    ENERGY      ID'#;
/* CHECK TO SEE IF THE LINE IS IN THE BANDPASS OF INTEREST AND H-
     APPROPRIATE IDENTIFICATION NUMBER */
    FOR I := 1 BY 5 TO 50000 DO
     IF MCCLAT[I] > UPPER THEN
      RETURN;
     END;
     FOR J := 1 TO NSPEC DO
      K := TRUNC(MCCLAT[I+4]);
      IF (K = IDENT[J]) .AND. (MCCLAT[I] >= LOWER) THEN
       NOMEG := NOMEG +1;
       OMEGSTR[NOMEG]:= CONTRACT(MCCLAT[I]);
       ALPHA[NOMEG]:= CONTRACT(MCCLAT[I+2]);
       SZ[NOMEG]:= CONTRACT(MCCLAT[I+1]);
       EL[NOMEG]:= CONTRACT(MCCLAT[I+3]);
       ILINE[NOMEG] := TRUNC(MCCLAT[I+4]);
/* SET UP THE MOLWT VECTOR TO INCLUDE THE MOLECULAR WEIGHTS OF THE
     INTERESTED SPECIES CORRESPONDING TO THE OMEGSTR VECTOR */
       MOLWT[NOMEG]:= CONTRACT(MWT[ILINE[NOMEG]]);
       PRINT(OMEGSTR[NOMEG],ALPHA[NOMEG],SZ[NOMEG],EL[NOMEG],
        ILINE[NOMEG]) #1X,F10.4,1X,F5.3,1X,E15.8,1X,F12.4,1X,I2#;
       END;
      END;
     END;
END;
```

Procedure DETERMN

DETERMN is called by TRANSMT. DETERMN determines the spectral lines included about the center wavenumber vector (OMEGA). The lines included fall into the interval OMEGA(1) - CMINV to OMEGA(last) + CMINV.

```
PROCEDURE DETERMN(OMEG1,OMEG2);
/* DETERMINE THE LINES TO BE INCLUDED IN THE INTERVAL ABOUT TH
     WAVENUMBER BY USING A BIT VECTOR, BA, THAT HAS A ONE IF TH
     TO BE INCLUDED.  THE CMPRS FUNCTION THEN PLACES THE APPROP
     LINES IN THE ARRAYS WAVEN(WAVENUMBER) AND IDENTN(SPECIES
     IDENTIFICATION NUMBER) */
    BIT VECTOR (NLIN) BA;
    SHORT REAL OMEG1,OMEG2;
    INTEGER IJ;
    WAVEN:= 0.; IDENTN:= 0;
    BA:= FALSE;
    BA:= (OMEGSTR>= (OMEG1-CMINV)) .AND. (OMEGSTR <= (OMEG2+CMINV)
    WAVEN:= BA.CMPRS.OMEGSTR;
    IDENTN:= BA.CMPRS.ILINE;
/* DETERMINE HOW MANY LINES ARE TO BE INCLUDED (NUMN) AND WHERE TH
     LINE OCCURS RELATIVE TO THE OMEGSTR ARRAY (FIRST) */
    NUMN:= ONES(BA);
    IJ:= 1;
    FIRST:= IJ;
    WHILE BA[IJ] = FALSE DO
     IJ:= IJ+1;
     FIRST:= IJ;
    ENDW;
ENDP;
```

Procedure VOIGT

VOIGT is called by TRANSMT. VOIGT determines which region of Pierluissi s approximation for the Voigt profile should be applied.

```
PROCEDURE VOIGT;
/* CALCULATE THE VOIGT ABSORPTION COEFFICIENT USING PIERLUISSI
   METHOD */
   X:= P/ALPHD(J)(FIRST+K-1) * 8.3256E-1;
   Y:= ABS(ALPHL(J)(FIRST+K-1)/ALPHD(J)(FIRST+K-1) * 8.3256E-1;
/* CHECK TO SEE IF X AND Y ARE IN REGION III */
   BF:= (Y>=5.0) .OR. (X>=5.0);
   IF ONES(BF) > 0 THEN CALL REGION3 END;
/* CHECK TO SEE IF X AND Y ARE IN REGION II */
   BE:= ((Y>= 1.0) .AND. (Y< 5.0)) .OR. ((X>=3.0) .AND. (X< 5.0));
   IF ONES(BE) > 0 THEN CALL REGION2 END;
/* CHECK TO SEE IF X AND Y ARE IN REGION I */
   BD:= (Y<1.0) .AND. (X<3.0);
   IF ONES(BD) > 0 THEN CALL REGION1 END;
END;
```

Procedure REGION1

REGION1 is called by VOIGT. REGION1 calculates the Voigt absorption coefficient for X and Y in region 1 (see ref. 8) of Pierluissi's method.

```
PROCEDURE REGION1;
/* CALCULATE THE VOIGT ABSORPTION COEFFICIENT FOR ANY X AND Y IN
     PIERLUISSI REGION 1 */
    SHORT REAL VECTOR (NINC) XSER,YSER,X1,Y1,S3,T3,C1,S1,T;
    SHORT REAL PISQ,XN,YN,XNEW,YNEW,X2,Y2;
    INTEGER N,NCOUNT,LL;
    SHORT REAL VECTOR (30) AN;
    INITIAL(AN=\1.0,-.33333333,0.1,-.238095238E-1,4.62962963E-3,
                -7.57575757E-4,1.068376068E-4,-1.322751323E-5,
                1.45891691E-6,-1.450385222E-7,1.312253296E-8,
                -1.089222104E-9,8.350702795E-11,-5.967794014E-12,
                3.955429516E-13,-2.46682701E-14,1.448326465E-15,
                -8.032735012E-17,4.221407289E-18,-2.107855192E-19,
                1.602516493E-20,-4.551046759E-22,1.977064754E-23,
                -8.230149299E-25,3.269260349E-26,-1.264167299E-27,
                4.678483352E-29,-1.669761793E-30,5.754191644E-32,
                -1.916942862E-33\);
    XSER:= 0.; YSER:= 0.; X1:= 0.; Y1:= 0.; S3:= 0.; T3:= 0.; C1:= 0.;
    S1:= X * X - Y * Y;
    T:= 2.0* X * Y;
    T3:= 80.CBPRS.T;
    S3:= 80.CBPRS.S1;
    X1:= 80.CBPRS.X;
    Y1:= 80.CBPRS.Y;
    NCOUNT:= ONES(80);
    FOR L:= 1 TO NCOUNT DO
     N:= FLOOR(6.842 * X1[L] + 0.0);
     IF N > 29 THEN N:= 29 ENDI;
     IF X1[L] = 0.0 THEN N:= 15 ENDI;
     XSER[L] := Y1[L];
     YSER[L] := -1. * X1[L];
     XN:= Y1[L];
```

```
    YN:= -1. * X1[L];
    X2:= -1. * S3[L];
    Y2:= -1. * T3[L];
    FOR LL:= 1 TO N DO
     XNEW:= XN * X2 - YN * Y2;
     YNEW:= Y2 * XN + YN * X2;
     XSER[L] := XSER[L] + XNEW * AN[LL+1];
     YSER[L] := YSER[L] + YNEW * AN[LL+1];
     XN:= XNEW;
     YN:= YNEW;
    END;
   END;
   PISQ:= 1.128379167;
   S1:= EXP(-1.*S3);
   T:= COS(-1.*T3);
   X1:= SIN(-1.*T3);
   Y1:= 1.0-PISQ*XSER;
   C1:= S1*(T*Y1+PISQ*X1*YSER);
   COMPABS[OD.CURRS.[IGTA[1,1,MINC]]]:= C1;
END;
```

Procedure REGION2

REGION2 is called by VOIGT. REGION2 calculates the Voigt absorption coefficient for X and Y in region 2 (see ref. 8) of Pierluissi's method.

```
PROCEDURE REGION2;
/* CALCULATE THE VOIGT ABSORPTION COEFFICIENT FOR ANY X AND Y IN
     PIERLUISSI REGION 2 */
   SHORT REAL VECTOR (NINC) R,F,G,H,X1,Y1,C1,T3,S3,S1,T,X2,Y2;
   SHORT REAL A6,A4,A2,A1,A3,A5;
   R:= 0.; F:= 0.; G:= 0.; H:= 0.; X1:= 0.; Y1:= 0.; C1:= 0.; T3:= 1.;
   S3:= 0.; X2:= 0.;  Y2:= 0.;
   S1:= X * X - Y * Y;
   T:= 2.0* X * Y;
   T3:= BE.CURRS.T;
   S3:= BE.CURRS.S1;
   X1:= BE.CURRS.X;
   Y1:= BE.CURRS.Y;
   R:= T3 * T3;
   T3:= T3 * X1;
   A6:= 5.52534370;
   F:= S3 - A6;
   A4:= 1.78449270;
   G:= S3 - A4;
   A2:= 0.19016350;
   H:= S3 - A2;
   A1:= 0.46131350;
   A3:= 0.09999216;
   A5:= 0.002883894;
   X1:= T3-H*Y1;
   S3:= H*H+R;
   S1:= T3-G*Y1;
   T:= G*G+R;
   X2:= T3-F*Y1;
   Y2:= F*F+R;
   C1:= A1*(X1/S3)+A3*(S1/T)+A5*(X2/Y2);
   COMPARSIDE.CURRS.(IOTA(1,1,NINC)):= C1;
END;
```

Procedure REGION3

REGION3 is called by VOIGT. REGION3 calculates the Voigt absorption coefficient for X and Y in region 3 (see ref. 8) of Pierluissi's method.

```
PROCEDURE REGION3;
/* CALCULATE THE VOIGT ABSORPTION COEFFICIENT FOR ANY X AND Y IN
     PIERLUISSI REGION 3 */
   SHORT REAL VECTOR (NINC) R,F,G,T3,S3,X1,Y1,C1,S1,T;
   SHORT REAL B1,B2,B3,B4;
   R:= 0.; F:= 0.; G:= 0.; T3:= 1.; S3:= 0.; X1:= 0.; Y1:= 0.; C1:= 0.;
   S1:= X * X - Y * Y;
   T:= 2.0* X * Y;
   T3:= BF.CHERS.T;
   S3:= BF.CHERS.S1;
   X1:= BF.CHERS.X;
   Y1:= BF.CHERS.Y;
   R:= T3 * T3;
   T3:= T3 * X1;
   B2:= 0.27525510;
   F:= S3 - B2;
   B4:= 2.72474500;
   G:= S3 - B4;
   B1:= 0.51242424;
   B3:= 0.05176536;
   S3:= T3-F*Y1;
   X1:= F*F+R;
   S1:= T3-G*Y1;
   T:= G*G+R;
   C1:= B1*(S3/X1)+B3*(S1/T);
   COMPABS(BF.CHERS.(IOTA(1,1,NINC))):= C1;
END;
```

Procedure SURFACE

SURFACE is called by TRANSMT. SURFACE calculates unattenuated surface emission using the Planck blackbody function.

```
PROCEDURE SURFACE;
/* CALCULATE UNATTENUATED SURFACE EMISSION USING PLANCK FUNCTION */
   FOR L:= 1 TO NSURF DO
    FOR M:= 1 TO NEMIS DO
     SURFCON:= U3/(EXP(C0*OMEGA/TSURF[L])-1.)*EMISS[M]*ATMTAU[K];
     SUMSURF[J,L,M][K]:= SUMSURF[J,L,M][K] + SUM(SURFCON);
    END;
   END;
END;
```

Procedure CHAPMAN

CHAPMAN is called by TRANSMT. CHAPMAN determines the slant path transmission using the Chapman polynomial (ref. 1).

```
PROCEDURE CHAPMAN;
/* DETERMINE THE SLANT PATH TRANSMISSION USING THE CHAPMAN FUNCTION
     FOR THETA GREATER THAN 60 DEGREES. THE NATURAL LOG OF THE CHAPMAN
     FUNCTION IS GIVEN BY AN 8TH DEGREE POLYNOMIAL IN THETA */
    FOR I:= 1 TO NIEN DO
     IF THETA[I] >= 90. THEN CHAP[I]:= 0. ELSE
      IF THETA[I] > 60. THEN
       CHAP[I]:= CONTRACT(COEF.PWL.THETA[I]);
       CHAP[I]:= EXP(-1. * CHAP[I]);
      ELSE
       CHAP[I]:= CONTRACT(1.0/COS(3.14159*THETA[I]/180.));
      END;
     END;
    END;
END;
```

Procedure SOLAR

SOLAR is called by TRANSMT. SOLAR calculates unattenuated solar radiation reflected by the surface of the Earth.

```
PROCEDURE SOLAR;
/* CALCULATE UNATTENUATED SOLAR RADIATION REFLECTED BY THE EARTH
     SURFACE */
    SHORT REAL CON;
/* LINEARLY INTERPOLATE SUNFLUX VALUES */
    FOR L:= 1 TO NINC DO
     IF OMEGA(L) < SUNW(1) THEN SUN(L) := 0.
     ELSE
      M:= 2;
      WHILE SUNW(M) < OMEGA(L) DO
       M:= M + 1;
      ENDW;
      CON:= (OMEGA(L) - SUNW(M-1))/DIFW(M-1);
      SUN(L):= SUNFLUX(M-1) + CON * DIFSUN(M-1);
     ENDI;
    ENDF;
/* CALCULATE THE TOTAL SUN CONTRIBUTION */
    FOR J:= 1 TO NLAY DO
     FOR L:= 1 TO NEMIS DO
      FOR N:= 1 TO NZEN DO
       FOR K:= 1 TO NIN DO
        TOTSUN:= SUN*SUNCON(L)(N)*TAUSLAT(K,N)*TRAN(K,J);
        SUMSUN(J,N,L)(K):= SUMSUN(J,N,L)(K) + SUN(TOTSUN);
       ENDF;
      ENDF;
     ENDF;
    ENDF;
ENDP;
ENDU;
```

APPENDIX D

INPUT PARAMETERS FOR A SAMPLE TEST CASE LISTED AS CARD IMAGES

```
   15    10     3     3
     5     1     2
2090.        2170.        .01          5.                  5      1.
0.           .1           .2           .3           .4           .5           .6           .7
.8           1.
  .9606        292.9    5.9551E+04      1
  .8964        290.4    6.3391E+04      1
  .8294        287.3    6.7753E+04      1
  .7630        283.4    7.2491E+04      1
  .6973        279.9    7.8271E+04      1
  .6311        276.0    8.4956E+04      1
  .5647        269.7    9.3106E+04      1
  .4991        262.3    1.0324E+05      1
  .4321        255.2    1.1502E+05      1
  .3650        247.9    1.3291E+05      1
  .2983        239.5    1.5559E+05      1
  .2316        227.4    1.9237E+05      1
  .1541        216.5    2.5329E+05      1
  .0957        216.1    4.4152E+05      2
  .0055        227.3    4.0799E+06      3
  1.739E-02 3.300E-06                                     1.0E-06

  1.429E-02 3.300E-06                                     1.0E-06

  1.144E-02 3.300E-06                                     1.0E-06

  9.666E-03 3.300E-06                                     1.0E-06

  5.989E-03 3.300E-06                                     1.0E-06

  4.120E-03 3.300E-06                                     1.0E-06

  2.531E-03 3.300E-06                                     1.0E-06

  1.674E-03 3.300E-06                                     1.0E-06

  1.120E-03 3.300E-06                                     1.0E-06

  6.653E-04 3.300E-06                                     1.0E-06

  3.332E-04 3.300E-06                                     1.0E-06

  9.919E-05 3.300E-06                                     1.0E-06

  1.906E-05 3.300E-06                                     1.0E-06

  [illegible] 3.300E-06                                  1.0E-06

  1.751E-05 3.300E-06                                    1.0E-06

     2     2
300.         296.
.33          .09
     2
65.          75.
```

APPENDIX E

OUTPUT LISTING FOR A SAMPLE TEST CASE

```
ATMOSPHERIC PARAMETERS
THE KEY FOR THE GAS SPECIES IS:
    1---H2O
    2---CO2
    3---O3
    4---N2O
    5---CO
    6---CH4
    7---O2
    8---SO2
    9---NO
    10--HCL
    11--NH3
    12--HNO3
LAYER  PRES (ATM)  TEMP (K)      THICK (CM)    PATH (ATM-CM)        5           1           2
 1        .9606     292.90     5.96610E+04   5.73103E+04     1.000E-06   1.739E-02   3.300E-04
 2        .8964     290.40     6.33910E+04   5.60237E+04     1.000E-06   1.429E-02   3.300E-04
 3        .8298     287.30     6.77530E+04   5.62214E+04     1.000E-06   1.144E-02   3.300E-04
 4        .7530     283.40     7.26930E+04   5.54648E+04     1.000E-06   8.664E-03   3.300E-04
 5        .6973     278.90     7.82710E+04   5.45784E+04     1.000E-06   5.989E-03   3.300E-04
 6        .6311     274.00     8.49560E+04   5.36157E+04     1.000E-06   4.120E-03   3.300E-04
 7        .5647     268.70     9.31660E+04   5.25769E+04     1.000E-06   2.631E-03   3.300E-04
 8        .4981     262.80     1.03240E+05   5.14238E+04     1.000E-06   1.678E-03   3.300E-04
 9        .4321     256.20     1.16020E+05   5.01322E+04     1.000E-06   1.120E-03   3.300E-04
10        .3650     247.90     1.32910E+05   4.85121E+04     1.000E-06   6.453E-04   3.300E-04
11        .2983     238.60     1.56560E+05   4.67018E+04     1.000E-06   3.332E-04   3.300E-04
12        .2314     227.40     1.92370E+05   4.45144E+04     1.000E-06   8.918E-05   3.300E-04
13        .1641     216.60     2.58280E+05   4.23837E+04     1.000E-06   1.004E-05   3.300E-04
14        .0957     216.10     4.41920E+05   4.22917E+04     1.000E-06   5.999E-06   3.300E-04
15        .0055     227.30     8.07890E+06   4.44339E+04     1.000E-06   1.761E-05   3.300E-04

THE INVESTIGATED POLLUTANT IS      5
THE WAVENUMBER INTERVAL IS     2080.00 TO     2170.00
THE MINIMUM SUBINTERVAL OF INTEGRATION IS       10.00 CM-1
THE INTEGRATING INCREMENT IS    .0100 CM-1
THE NUMBER OF INTEGRATION POINTS IS        9000
```

```
LAYER     1
THE LINE PROFILE IS LORENTZ
MULT   =    0.0          1.0000E-01  2.0000E-01  3.0000E-01  4.0000E-01  5.0000E-01  6.0000E-01  7.0000E-01  8.0000E-01  1.0000E+00
ATMTAU =        .84388      .83617      .82920      .82208      .81707      .81173      .80674      .80211      .79780      .78987
ATMRAD =  4.8092E-06  5.0378E-06  5.2447E-06  5.4322E-06  5.6046E-06  5.7635E-06  5.9117E-06  6.0493E-06  6.1772E-06  6.4133E-06


SURFACE EMISSIVITY =       .8000
 SURFACE TEMPERATURE =   300.0000
   SURF=   2.8595E-05  2.8338E-05  2.8105E-05  2.7893E-05  2.7699E-05  2.7520E-05  2.7353E-05  2.7198E-05  2.7054E-05  2.6788E-05

SURFACE EMISSIVITY =       .8000
 SURFACE TEMPERATURE =   296.0000
   SURF=   2.4919E-05  2.4694E-05  2.4498E-05  2.4307E-05  2.4130E-05  2.3982E-05  2.3836E-05  2.3701E-05  2.3575E-05  2.3344E-05

SURFACE EMISSIVITY =       .9800
 SURFACE TEMPERATURE =   300.0000
   SURF=   3.1845E-05  3.1558E-05  3.1298E-05  3.1063E-05  3.0846E-05  3.0647E-05  3.0461E-05  3.0288E-05  3.0128E-05  2.9832E-05

SURFACE EMISSIVITY =       .9800
 SURFACE TEMPERATURE =   296.0000
   SURF=   2.7750E-05  2.7500E-05  2.7274E-05  2.7069E-05  2.6881E-05  2.6707E-05  2.6545E-05  2.6394E-05  2.6255E-05  2.5996E-05


SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =       .8000
   SUN =   1.5093E-06  1.3854E-06  1.3261E-06  1.2808E-06  1.2430E-06  1.2100E-06  1.1801E-06  1.1529E-06  1.1278E-06  1.0825E-06

SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =       .9800
   SUN =   2.5155E-07  2.3090E-07  2.2102E-07  2.1347E-07  2.0717E-07  2.0166E-07  1.9669E-07  1.9215E-07  1.8796E-07  1.8041E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =       .8000
   SUN =   3.9819E-07  3.4325E-07  3.1819E-07  2.9915E-07  2.8347E-07  2.6991E-07  2.5793E-07  2.4720E-07  2.3746E-07  2.2030E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =       .9800
   SUN =   6.6364E-08  5.7208E-08  5.3031E-08  4.9859E-08  4.7246E-08  4.4985E-08  4.2988E-08  4.1200E-08  3.9576E-08  3.6717E-08
```

```
LAYER     2
THE LINE PROFILE IS LORENTZ
MULT   =   0.0          1.0000E-01  2.0000E-01  3.0000E-01  4.0000E-01  5.0000E-01  6.0000E-01  7.0000E-01  8.0000E-01  1.0000E+00
ATMTAU =         .78574      .77219      .76100      .75156      .74337      .73611      .72956      .72362      .71815      .70827
ATMRAD =   6.2409E-06  6.6214E-06  6.9344E-06  7.1975E-06  7.4255E-06  7.6268E-06  7.8083E-06  7.9729E-06  8.1239E-06  8.3971E-06


SURFACE EMISSIVITY =        .8800
 SURFACE TEMPERATURE =   300.0000
   SURF=   2.6586E-05  2.6134E-05  2.5761E-05  2.5445E-05  2.5172E-05  2.4929E-05  2.4710E-05  2.4511E-05  2.4328E-05  2.3998E-05

SURFACE EMISSIVITY =        .8800
 SURFACE TEMPERATURE =   296.0000
   SURF=   2.3167E-05  2.2773E-05  2.2448E-05  2.2174E-05  2.1935E-05  2.1724E-05  2.1533E-05  2.1360E-05  2.1200E-05  2.0912E-05

SURFACE EMISSIVITY =        .9800
 SURFACE TEMPERATURE =   300.0000
   SURF=   2.9607E-05  2.9104E-05  2.8688E-05  2.8337E-05  2.8032E-05  2.7762E-05  2.7516E-05  2.7297E-05  2.7093E-05  2.6725E-05

SURFACE EMISSIVITY =        .9800
 SURFACE TEMPERATURE =   296.0000
   SURF=   2.5799E-05  2.5361E-05  2.4999E-05  2.4693E-05  2.4428E-05  2.4192E-05  2.3960E-05  2.3787E-05  2.3610E-05  2.3289E-05


SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =        .8800
   SUN =   1.4546E-06  1.3310E-06  1.2718E-06  1.2266E-06  1.1889E-06  1.1559E-06  1.1261E-06  1.0990E-06  1.0740E-06  1.0287E-06

SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =        .9800
   SUN =   2.4244E-07  2.2183E-07  2.1197E-07  2.0443E-07  1.9814E-07  1.9265E-07  1.8769E-07  1.8317E-07  1.7899E-07  1.7148E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =        .8800
   SUN =   3.8639E-07  3.3402E-07  3.0921E-07  2.9037E-07  2.7467E-07  2.6140E-07  2.4964E-07  2.3905E-07  2.2945E-07  2.1255E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =        .9800
   SUN =   6.4731E-08  5.5670E-08  5.1535E-08  4.8396E-08  4.5812E-08  4.3577E-08  4.1606E-08  3.9842E-08  3.8241E-08  3.5425E-08
```

```
LAYER     3
THE LINE PROFILE IS LORENTZ
MULT   =   0.0          1.0000E-01  2.0000E-01  3.0000E-01  4.0000E-01  5.0000E-01  6.0000E-01  7.0000E-01  8.0000E-01  1.0000E+00
ATMTAU =        .75176      .73330      .71932      .70812      .69869      .69047      .68311      .67646      .67034      .65926
ATMRAD =   6.8177E-06  7.3027E-06  7.6656E-06  7.9533E-06  8.1942E-06  8.4031E-06  8.5898E-06  8.7508E-06  8.9128E-06  9.1929E-06


SURFACE EMISSIVITY =        .8000
 SURFACE TEMPERATURE =   300.0000
   SURF=   2.5409E-05  2.4795E-05  2.4329E-05  2.3956E-05  2.3641E-05  2.3366E-05  2.3120E-05  2.2898E-05  2.2696E-05  2.2323E-05
SURFACE EMISSIVITY =        .8000
 SURFACE TEMPERATURE =   296.0000
   SURF=   2.2142E-05  2.1607E-05  2.1201E-05  2.0875E-05  2.0601E-05  2.0362E-05  2.0147E-05  1.9954E-05  1.9776E-05  1.9453E-05
SURFACE EMISSIVITY =        .9000
 SURFACE TEMPERATURE =   300.0000
   SURF=   2.8297E-05  2.7613E-05  2.7094E-05  2.6678E-05  2.6327E-05  2.6021E-05  2.5747E-05  2.5500E-05  2.5272E-05  2.4860E-05
SURFACE EMISSIVITY =        .9000
 SURFACE TEMPERATURE =   296.0000
   SURF=   2.4658E-05  2.4062E-05  2.3610E-05  2.3247E-05  2.2942E-05  2.2675E-05  2.2437E-05  2.2241E-05  2.2023E-05  2.1664E-05

SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =        .8000
   SUN =   1.4175E-06  1.2930E-06  1.2336E-06  1.1882E-06  1.1502E-06  1.1171E-06  1.0873E-06  1.0601E-06  1.0350E-06  9.8965E-07
SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =        .9000
   SUN =   2.3625E-07  2.1551E-07  2.0560E-07  1.9603E-07  1.9171E-07  1.8619E-07  1.8121E-07  1.7668E-07  1.7249E-07  1.6497E-07
SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =        .8000
   SUN =   3.8150E-07  3.2737E-07  3.0267E-07  2.8393E-07  2.6851E-07  2.5520E-07  2.4345E-07  2.3295E-07  2.2343E-07  2.0669E-07
SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =        .9000
   SUN =   6.3583E-08  5.4562E-08  5.0446E-08  4.7321E-08  4.4752E-08  4.2533E-08  4.0576E-08  3.8825E-08  3.7238E-08  3.4449E-08
```

```
LAYER     4
THE LINE PROFILE IS LORENTZ
MULT   =   0.0          1.0000E-01  2.0000E-01  3.0000E-01  4.0000E-01  5.0000E-01  6.0000E-01  7.0000E-01  8.0000E-01  1.0000E+00
ATMTAU =        .73092      .70821      .69227      .67993      .66969      .66080      .65284      .64563      .63898      .63292
ATMRAD =   6.9580E-06  7.5089E-06  7.8846E-06  8.1696E-06  8.4043E-06  8.6066E-06  8.7876E-06  8.9512E-06  9.1019E-06  9.3760E-06


SURFACE EMISSIVITY =       .8000
 SURFACE TEMPERATURE =   300.0000
   SURF=   2.4687E-05  2.3931E-05  2.3400E-05  2.2989E-05  2.2647E-05  2.2351E-05  2.2065E-05  2.1844E-05  2.1622E-05  2.1289E-05

SURFACE EMISSIVITY =       .8000
 SURFACE TEMPERATURE =   296.0000
   SURF=   2.1532E-05  2.0854E-05  2.0391E-05  2.0033E-05  1.9735E-05  1.9477E-05  1.9245E-05  1.9036E-05  1.8842E-05  1.8491E-05

SURFACE EMISSIVITY =       .9000
 SURFACE TEMPERATURE =   300.0000
   SURF=   2.7492E-05  2.6651E-05  2.6060E-05  2.5601E-05  2.5221E-05  2.4890E-05  2.4594E-05  2.4326E-05  2.4079E-05  2.3631E-05

SURFACE EMISSIVITY =       .9000
 SURFACE TEMPERATURE =   296.0000
   SURF=   2.3956E-05  2.3223E-05  2.2708E-05  2.2309E-05  2.1978E-05  2.1690E-05  2.1432E-05  2.1199E-05  2.0983E-05  2.0592E-05


SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =       .8000
   SUM =   1.3930E-06  1.2671E-06  1.2071E-06  1.1612E-06  1.1229E-06  1.0895E-06  1.0594E-06  1.0320E-06  1.0067E-06  9.6132E-07

SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =       .9000
   SUM =   2.3217E-07  2.1118E-07  2.0118E-07  1.9353E-07  1.8715E-07  1.8159E-07  1.7656E-07  1.7200E-07  1.6778E-07  1.6022E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =       .8000
   SUM =   3.7688E-07  3.2273E-07  2.9803E-07  2.7930E-07  2.6391E-07  2.5062E-07  2.3891E-07  2.2844E-07  2.1896E-07  2.0231E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =       .9000
   SUM =   6.2813E-08  5.3788E-08  4.9672E-08  4.6550E-08  4.3985E-08  4.1769E-08  3.9818E-08  3.8074E-08  3.6493E-08  3.3719E-08
```

```
LAYER     5
THE LINE PROFILE IS LORENTZ
MULT   =    0.0         1.0000E-01  2.0000E-01  3.0000E-01  4.0000E-01  5.0000E-01  6.0000E-01  7.0000E-01  8.0000E-01  1.0000E+00
ATMTAU =        .71847      .69195      .67455      .66138      .65048      .64102      .63253      .62482      .61771      .60476
ATMRAD =    6.9014E-06  7.4842E-06  7.8483E-06  8.1164E-06  8.3359E-06  8.5255E-06  8.6959E-06  8.8503E-06  8.9930E-06  9.2531E-06


SURFACE EMISSIVITY =      .8000
 SURFACE TEMPERATURE =  300.0000
   SURF=   2.4253E-05  2.3372E-05  2.2792E-05  2.2353E-05  2.1990E-05  2.1674E-05  2.1391E-05  2.1134E-05  2.0896E-05  2.0464E-05

SURFACE EMISSIVITY =      .8000
 SURFACE TEMPERATURE =  296.0000
   SURF=   2.1134E-05  2.0366E-05  1.9061E-05  1.9479E-05  1.9162E-05  1.8887E-05  1.8641E-05  1.8416E-05  1.8210E-05  1.7833E-05

SURFACE EMISSIVITY =      .9000
 SURFACE TEMPERATURE =  300.0000
   SURF=   2.7009E-05  2.6028E-05  2.5382E-05  2.4893E-05  2.4489E-05  2.4137E-05  2.3822E-05  2.3535E-05  2.3271E-05  2.2789E-05

SURFACE EMISSIVITY =      .9000
 SURFACE TEMPERATURE =  296.0000
   SURF=   2.3535E-05  2.2680E-05  2.2116E-05  2.1692E-05  2.1340E-05  2.1034E-05  2.0759E-05  2.0509E-05  2.0279E-05  1.9860E-05


SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =      .8000
   SUM =   1.3778E-06  1.2498E-06  1.1891E-06  1.1426E-06  1.1036E-06  1.0700E-06  1.0396E-06  1.0119E-06  9.8632E-07  9.4051E-07

SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =      .9000
   SUM =   2.2964E-07  2.0831E-07  1.9618E-07  1.9043E-07  1.8397E-07  1.7834E-07  1.7326E-07  1.6865E-07  1.6439E-07  1.5675E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =      .8000
   SUM =   3.7398E-07  3.1961E-07  2.9404E-07  2.7606E-07  2.6064E-07  2.4733E-07  2.3562E-07  2.2515E-07  2.1568E-07  1.9986E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =      .9000
   SUM =   6.2330E-08  5.3268E-08  4.9139E-08  4.6010E-08  4.3439E-08  4.1222E-08  3.9270E-08  3.7526E-08  3.5947E-08  3.3176E-08
```

```
LAYER    6
THE LINE PROFILE IS LORENTZ
MULT   =   0.0        1.0000E-01  2.0000E-01  3.0000E-01  4.0000E-01  5.0000E-01  6.0000E-01  7.0000E-01  8.0000E-01  1.0000E+00
ATMTAU =      .71069      .68075      .66225      .64840      .63695      .62676      .61606      .60985      .60231      .58660
ATMRAD =   6.7[illegible]E-06  7.3663E-06  7.7037E-06  7.9482E-06  8.1489E-06  8.3232E-06  8.4805E-06  8.6235E-06  8.7557E-06  8.9972E-06


SURFACE EMISSIVITY =      .8800
 SURFACE TEMPERATURE =   300.0000
   SURF=   2.3381E-05  2.2986E-05  2.2370E-05  2.1909E-05  2.1527E-05  2.1194E-05  2.0895E-05  2.0623E-05  2.0372E-05  1.9914E-05

SURFACE EMISSIVITY =      .8800
 SURFACE TEMPERATURE =   296.0000
   SURF=   2.0397E-05  2.0030E-05  1.9494E-05  1.9092E-05  1.8759E-05  1.8469E-05  1.8209E-05  1.7972E-05  1.7753E-05  1.7354E-05

SURFACE EMISSIVITY =      .9800
 SURFACE TEMPERATURE =   300.0000
   SURF=   2.6706E-05  2.5599E-05  2.4912E-05  2.4399E-05  2.3973E-05  2.3603E-05  2.3270E-05  2.2967E-05  2.2687E-05  2.2176E-05

SURFACE EMISSIVITY =      .9800
 SURFACE TEMPERATURE =   296.0000
   SURF=   2.3271E-05  2.2307E-05  2.1709E-05  2.1261E-05  2.0891E-05  2.0566E-05  2.0278E-05  2.0014E-05  1.9770E-05  1.9326E-05


SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =      .8800
   SUM =   1.3681E-06  1.2379E-06  1.1762E-06  1.1291E-06  1.0898E-06  1.0556E-06  1.0246E-06  9.9675E-07  9.7090E-07  9.2462E-07

SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =      .9800
   SUM =   2.2802E-07  2.0631E-07  1.9604E-07  1.8819E-07  1.8164E-07  1.7593E-07  1.7079E-07  1.6612E-07  1.6182E-07  1.5410E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =      .8800
   SUM =   3.7212E-07  3.1743E-07  2.9254E-07  2.7369E-07  2.5821E-07  2.4487E-07  2.3313E-07  2.2265E-07  2.1316E-07  1.9654E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =      .9800
   SUM =   6.2019E-08  5.2905E-08  4.6757E-08  4.5614E-08  4.3035E-08  4.0811E-08  3.8855E-08  3.7108E-08  3.5527E-08  3.2757E-08
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LAYER     7
THE LINE PROFILE IS LORENTZ
MULT   =    0.0         1.0000E-01  2.0000E-01  3.0000E-01  4.0000E-01  5.0000E-01  6.0000E-01  7.0000E-01  8.0000E-01  1.0000E+00
ATMTAU =        .70584      .67285      .65349      .63906      .62710      .61665      .60726      .59871      .59079      .57638
ATMRAD =    6.6571E-06  7.2280E-06  7.5306E-06  7.7490E-06  7.9295E-06  8.0874E-06  8.2305E-06  8.3606E-06  8.4812E-06  8.7615E-06


SURFACE EMISSIVITY =        .8000
 SURFACE TEMPERATURE =   300.0000
   SURF=    2.3810E-05  2.2715E-05  2.2070E-05  2.1589E-05  2.1190E-05  2.0842E-05  2.0529E-05  2.0243E-05  1.9979E-05  1.9498E-05

SURFACE EMISSIVITY =        .8000
 SURFACE TEMPERATURE =   296.0000
   SURF=    2.0748E-05  1.9794E-05  1.9232E-05  1.8813E-05  1.8466E-05  1.8163E-05  1.7890E-05  1.7641E-05  1.7411E-05  1.6992E-05

SURFACE EMISSIVITY =        .9800
 SURFACE TEMPERATURE =   300.0000
   SURF=    2.6516E-05  2.5296E-05  2.4578E-05  2.4042E-05  2.3598E-05  2.3211E-05  2.2862E-05  2.2544E-05  2.2250E-05  2.1714E-05

SURFACE EMISSIVITY =        .9800
 SURFACE TEMPERATURE =   296.0000
   SURF=    2.3105E-05  2.2043E-05  2.1417E-05  2.0951E-05  2.0564E-05  2.0227E-05  1.9922E-05  1.9646E-05  1.9389E-05  1.8923E-05


SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =        .8000
   SUN =    1.3620E-06  1.2294E-06  1.1669E-06  1.1192E-06  1.0793E-06  1.0447E-06  1.0134E-06  9.8509E-07  9.5894E-07  9.1217E-07

SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =        .9800
   SUN =    2.2699E-07  2.0491E-07  1.9449E-07  1.8653E-07  1.7989E-07  1.7411E-07  1.6892E-07  1.6418E-07  1.5982E-07  1.5203E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =        .8000
   SUN =    3.7094E-07  3.1589E-07  2.9086E-07  2.7191E-07  2.5637E-07  2.4298E-07  2.3120E-07  2.2076E-07  2.1119E-07  1.9455E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =        .9800
   SUN =    6.1823E-08  5.2648E-08  4.8477E-08  4.5319E-08  4.2729E-08  4.0498E-08  3.8534E-08  3.6783E-08  3.5199E-08  3.2425E-08
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LAYER    8
THE LINE PROFILE IS LORENTZ
MULT   =   0.0          1.0000E-01  2.0000E-01  3.0000E-01  4.0000E-01  5.0000E-01  6.0000E-01  7.0000E-01  8.0000E-01  1.0000E+00
ATMTAU =       .70263       .66695      .64690      .63197      .61956      .60870      .59892      .59002      .58177      .56675
ATMRAD =   6.5553E-06  7.0911E-06  7.3558E-06  7.5481E-06  7.7085E-06  7.8495E-06  7.9775E-06  8.0963E-06  8.2023E-06  8.3998E-06


SURFACE EMISSIVITY =       .8800
 SURFACE TEMPERATURE =   300.0000
   SURF=   2.3696E-05  2.2511E-05  2.1844E-05  2.1347E-05  2.0933E-05  2.0571E-05  2.0245E-05  1.9967E-05  1.9672E-05  1.9171E-05

SURFACE EMISSIVITY =       .8800
 SURFACE TEMPERATURE =   296.0000
   SURF=   2.0648E-05  1.9617E-05  1.9035E-05  1.8602E-05  1.8242E-05  1.7926E-05  1.7642E-05  1.7383E-05  1.7143E-05  1.6707E-05

SURFACE EMISSIVITY =       .9800
 SURFACE TEMPERATURE =   300.0000
   SURF=   2.6389E-05  2.5069E-05  2.4326E-05  2.3773E-05  2.3312E-05  2.2909E-05  2.2545E-05  2.2214E-05  2.1908E-05  2.1349E-05

SURFACE EMISSIVITY =       .9800
 SURFACE TEMPERATURE =   296.0000
   SURF=   2.2995E-05  2.1846E-05  2.1198E-05  2.0716E-05  2.0315E-05  1.9963E-05  1.9647E-05  1.9358E-05  1.9091E-05  1.8605E-05


SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =       .8800
   SUN =   1.3578E-06  1.2231E-06  1.1598E-06  1.1114E-06  1.0711E-06  1.0360E-06  1.0044E-06  9.7571E-07  9.4929E-07  9.0206E-07

SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =       .9800
   SUN =   2.2631E-07  2.0385E-07  1.9330E-07  1.8523E-07  1.7851E-07  1.7266E-07  1.6744E-07  1.6262E-07  1.5822E-07  1.5034E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =       .8800
   SUN =   3.7016E-07  3.1474E-07  2.8957E-07  2.7052E-07  2.5491E-07  2.4147E-07  2.2965E-07  2.1912E-07  2.0959E-07  1.9291E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =       .9800
   SUN =   6.1693E-08  5.2456E-08  4.8262E-08  4.5087E-08  4.2485E-08  4.0244E-08  3.8275E-08  3.6519E-08  3.4931E-08  3.2152E-08
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LAYER    9
THE LINE PROFILE IS LORENTZ
MULT   =    0.0          1.0000E-01  2.0000E-01  3.0000E-01  4.0000E-01  5.0000E-01  6.0000E-01  7.0000E-01  8.0000E-01  1.0000E+00
ATPTAU =          .70033      .66231      .64172      .62635      .61353      .60231      .59226      .58297      .57443      .56665
ATPRAD =    6.4739E-06  6.9619E-06  7.1693E-06  7.3566E-06  7.4977E-06  7.6222E-06  7.7357E-06  7.8389E-06  7.9345E-06  8.1089E-06


SURFACE EMISSIVITY =       .8000
 SURFACE TEMPERATURE =   300.0000
   SURF=    2.3613E-05  2.2351E-05  2.1666E-05  2.1154E-05  2.0727E-05  2.0353E-05  2.0015E-05  1.9706E-05  1.9423E-05  1.8904E-05

SURFACE EMISSIVITY =       .8000
 SURFACE TEMPERATURE =   296.0000
   SURF=    2.0576E-05  1.9477E-05  1.8860E-05  1.8434E-05  1.8062E-05  1.7736E-05  1.7442E-05  1.7174E-05  1.6926E-05  1.6474E-05

SURFACE EMISSIVITY =       .9800
 SURFACE TEMPERATURE =   300.0000
   SURF=    2.6297E-05  2.4891E-05  2.4128E-05  2.3558E-05  2.3082E-05  2.2666E-05  2.2290E-05  2.1947E-05  2.1630E-05  2.1052E-05

SURFACE EMISSIVITY =       .9800
 SURFACE TEMPERATURE =   296.0000
   SURF=    2.2915E-05  2.1690E-05  2.1026E-05  2.0529E-05  2.0115E-05  1.9752E-05  1.9425E-05  1.9126E-05  1.8849E-05  1.8346E-05


SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =        .8000
   SUN =    1.3549E-06  1.2181E-06  1.1541E-06  1.1051E-06  1.0643E-06  1.0288E-06  9.9650E-07  9.6794E-07  9.4126E-07  8.9360E-07

SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =        .9800
   SUN =    2.2582E-07  2.0302E-07  1.9235E-07  1.8418E-07  1.7739E-07  1.7147E-07  1.6615E-07  1.6132E-07  1.5688E-07  1.4893E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =        .8000
   SUN =    3.6960E-07  3.1383E-07  2.8853E-07  2.6939E-07  2.5371E-07  2.4022E-07  2.2836E-07  2.1760E-07  2.0825E-07  1.9154E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =        .9800
   SUN =    6.1600E-08  5.2305E-08  4.8088E-08  4.4898E-08  4.2285E-08  4.0036E-08  3.8061E-08  3.6299E-08  3.4706E-08  3.1924E-08
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LAYER   10
THE LINE PROFILE IS LORENTZ
MULT   =    0.0          1.0000E-01  2.0000E-01  3.0000E-01  4.0000E-01  5.0000E-01  6.0000E-01  7.0000E-01  8.0000E-01  1.0000E+00
ATMTAU =        .69468      .65865      .63762      .62187      .60870      .59716      .58676      .57726      .56847      .55247
ATMRAD =    6.4175E-06  6.8407E-06  7.0407E-06  7.1849E-06  7.3073E-06  7.4157E-06  7.5147E-06  7.6043E-06  7.6874E-06  7.8385E-06

SURFACE EMISSIVITY =         .8000
 SURFACE TEMPERATURE =    300.0000
   SURF=    2.3554E-05  2.2225E-05  2.1525E-05  2.1001E-05  2.0562E-05  2.0177E-05  1.9836E-05  1.9513E-05  1.9220E-05  1.8686E-05
SURFACE EMISSIVITY =         .8000
 SURFACE TEMPERATURE =    296.0000
   SURF=    2.0525E-05  1.9367E-05  1.8758E-05  1.8301E-05  1.7919E-05  1.7583E-05  1.7281E-05  1.7005E-05  1.6749E-05  1.6284E-05
SURFACE EMISSIVITY =         .9800
 SURFACE TEMPERATURE =    300.0000
   SURF=    2.6230E-05  2.4751E-05  2.3971E-05  2.3387E-05  2.2899E-05  2.2470E-05  2.2083E-05  2.1731E-05  2.1404E-05  2.0809E-05
SURFACE EMISSIVITY =         .9800
 SURFACE TEMPERATURE =    296.0000
   SURF=    2.2857E-05  2.1568E-05  2.0889E-05  2.0380E-05  1.9955E-05  1.9581E-05  1.9245E-05  1.8937E-05  1.8653E-05  1.8134E-05

SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =        .8000
   SUN =    1.3528E-06  1.2142E-06  1.1495E-06  1.1000E-06  1.0588E-06  1.0229E-06  9.9073E-07  9.6151E-07  9.3461E-07  8.8458E-07
SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =        .9800
   SUN =    2.2546E-07  2.0237E-07  1.9158E-07  1.8333E-07  1.7646E-07  1.7049E-07  1.6512E-07  1.6025E-07  1.5577E-07  1.4776E-07
SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =        .8000
   SUN =    3.6921E-07  3.1311E-07  2.8769E-07  2.6847E-07  2.5273E-07  2.3918E-07  2.2736E-07  2.1670E-07  2.0713E-07  1.9040E-07
SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =        .9800
   SUN =    6.1535E-08  5.2186E-08  4.7946E-08  4.4745E-08  4.2121E-08  3.9864E-08  3.7863E-08  3.6117E-08  3.4522E-08  3.1733E-08
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LAYER   11
THE LINE PROFILE IS LORENTZ
MULT   =   0.0          1.0000E-01  2.0000E-01  3.0000E-01  4.0000E-01  5.0000E-01  6.0000E-01  7.0000E-01  8.0000E-01  1.0000E+00
ATMTAU =        .69744      .65573      .63635      .61827      .60400      .59299      .58233      .57260      .56360      .54722
ATMRAD =   6.3816E-06  6.7540E-06  6.9160E-06  7.0415E-06  7.1401E-06  7.2426E-06  7.3286E-06  7.4066E-06  7.4787E-06  7.6091E-06


SURFACE EMISSIVITY =       .8000
 SURFACE TEMPERATURE =   300.0000
   SURF=   2.3509E-05  2.2124E-05  2.1413E-05  2.0878E-05  2.0429E-05  2.0035E-05  1.9679E-05  1.9355E-05  1.9054E-05  1.8507E-05

SURFACE EMISSIVITY =       .8000
 SURFACE TEMPERATURE =   296.0000
   SURF=   2.0405E-05  1.9280E-05  1.8660E-05  1.8193E-05  1.7803E-05  1.7459E-05  1.7150E-05  1.6867E-05  1.6605E-05  1.6124E-05

SURFACE EMISSIVITY =       .9800
 SURFACE TEMPERATURE =   300.0000
   SURF=   2.6100E-05  2.4639E-05  2.3846E-05  2.3250E-05  2.2750E-05  2.2311E-05  2.1916E-05  2.1554E-05  2.1228E-05  2.0610E-05

SURFACE EMISSIVITY =       .9800
 SURFACE TEMPERATURE =   296.0000
   SURF=   2.2813E-05  2.1471E-05  2.0780E-05  2.0261E-05  1.9826E-05  1.9443E-05  1.9098E-05  1.8784E-05  1.8492E-05  1.7961E-05


SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =       .8000
   SUN =   1.3512E-06  1.2111E-06  1.1458E-06  1.0958E-06  1.0543E-06  1.0181E-06  9.8565E-07  9.5621E-07  9.2912E-07  8.8678E-07

SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =       .9800
   SUN =   2.2521E-07  2.0185E-07  1.9096E-07  1.8264E-07  1.7571E-07  1.6969E-07  1.6426E-07  1.5937E-07  1.5485E-07  1.4680E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =       .8000
   SUN =   3.4893E-07  3.1255E-07  2.8701E-07  2.6772E-07  2.5192E-07  2.3834E-07  2.2642E-07  2.1580E-07  2.0621E-07  1.8960E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =       .9800
   SUN =   5.8489E-08  5.2001E-08  4.7635E-08  4.4619E-08  4.1987E-08  3.9723E-08  3.7737E-08  3.5967E-08  3.4369E-08  3.1576E-08
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LAYER    12
THE LINE PROFILE IS LORENTZ
MULT   =    0.0         1.0000E-01  2.0000E-01  3.0000E-01  4.0000E-01  5.0000E-01  6.0000E-01  7.0000E-01  8.0000E-01  1.0000E+00
ATMTAU =        .69651      .65343      .63177      .61542      .60170      .58966      .57860      .56866      .55970      .54300
ATMRAD =    6.3620E-06  6.6797E-06  6.8206E-06  6.9301E-06  7.0238E-06  7.1070E-06  7.1827E-06  7.2507E-06  7.3135E-06  7.4267E-06


SURFACE EMISSIVITY =       .6000
 SURFACE TEMPERATURE =   300.0000
   SURF=    2.3474E-05  2.2045E-05  2.1324E-05  2.0760E-05  2.0323E-05  1.9921E-05  1.9559E-05  1.9228E-05  1.8922E-05  1.8364E-05

SURFACE EMISSIVITY =       .8000
 SURFACE TEMPERATURE =   296.0000
   SURF=    2.0455E-05  1.9211E-05  1.8583E-05  1.8100E-05  1.7710E-05  1.7360E-05  1.7045E-05  1.6756E-05  1.6490E-05  1.6004E-05

SURFACE EMISSIVITY =       .9000
 SURFACE TEMPERATURE =   300.0000
   SURF=    2.6142E-05  2.4550E-05  2.3748E-05  2.3141E-05  2.2632E-05  2.2185E-05  2.1781E-05  2.1413E-05  2.1072E-05  2.0451E-05

SURFACE EMISSIVITY =       .9000
 SURFACE TEMPERATURE =   296.0000
   SURF=    2.2780E-05  2.1394E-05  2.0694E-05  2.0166E-05  1.9723E-05  1.9333E-05  1.8982E-05  1.8661E-05  1.8363E-05  1.7822E-05


SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =       .8000
   SUN =    1.3501E-06  1.2086E-06  1.1428E-06  1.0925E-06  1.0506E-06  1.0143E-06  9.8157E-07  9.5195E-07  9.2470E-07  8.7611E-07

SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =       .9800
   SUN =    2.2562E-07  2.0143E-07  1.9047E-07  1.8208E-07  1.7511E-07  1.6904E-07  1.6360E-07  1.5866E-07  1.5412E-07  1.4602E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =       .8000
   SUN =    3.6873E-07  3.1210E-07  2.8646E-07  2.6712E-07  2.5120E-07  2.3766E-07  2.2572E-07  2.1500E-07  2.0548E-07  1.8870E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =       .9800
   SUN =    6.1455E-08  5.2017E-08  4.7744E-08  4.4520E-08  4.1866E-08  3.9610E-08  3.7620E-08  3.5847E-08  3.4246E-08  3.1450E-08
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LAYER   13
THE LINE PROFILE IS LORENTZ
MULT   =   0.0         1.0000E-01  2.0000E-01  3.0000E-01  4.0000E-01  5.0000E-01  6.0000E-01  7.0000E-01  8.0000E-01  1.0000E+00
ATMTAU =       .69576      .65166      .62980      .61323      .59932      .58719      .57606      .56601      .55670      .53976
ATMRAD =  6.3481E-06  6.6222E-06  6.7496E-06  6.8493E-06  6.9344E-06  7.0097E-06  7.0766E-06  7.1390E-06  7.1951E-06  7.2959E-06


SURFACE EMISSIVITY =      .8800
 SURFACE TEMPERATURE =   300.0000
   SURF=   2.3447E-05  2.1984E-05  2.1256E-05  2.0705E-05  2.0241E-05  1.9834E-05  1.9466E-05  1.9130E-05  1.8819E-05  1.8254E-05

SURFACE EMISSIVITY =      .8800
 SURFACE TEMPERATURE =   296.0000
   SURF=   2.0432E-05  1.9157E-05  1.8523E-05  1.8043E-05  1.7639E-05  1.7280E-05  1.6964E-05  1.6671E-05  1.6400E-05  1.5908E-05

SURFACE EMISSIVITY =      .9800
 SURFACE TEMPERATURE =   300.0000
   SURF=   2.6111E-05  2.4462E-05  2.3672E-05  2.3057E-05  2.2541E-05  2.2087E-05  2.1676E-05  2.1304E-05  2.0958E-05  2.0328E-05

SURFACE EMISSIVITY =      .9800
 SURFACE TEMPERATURE =   296.0000
   SURF=   2.2753E-05  2.1334E-05  2.0626E-05  2.0093E-05  1.9643E-05  1.9246E-05  1.8891E-05  1.8566E-05  1.8264E-05  1.7715E-05


SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =       .8800
   SUN =   1.3492E-06  1.2667E-06  1.1406E-06  1.0909E-06  1.0479E-06  1.0113E-06  9.7645E-07  9.4470E-07  9.2134E-07  8.7256E-07

SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =       .9800
   SUN =   2.2487E-07  2.0112E-07  1.9009E-07  1.8166E-07  1.7464E-07  1.6855E-07  1.6308E-07  1.5812E-07  1.5356E-07  1.4543E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =       .8800
   SUN =   3.6859E-07  3.1177E-07  2.8607E-07  2.6667E-07  2.5079E-07  2.3715E-07  2.2519E-07  2.1454E-07  2.0492E-07  1.8813E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =       .9800
   SUN =   6.1431E-08  5.1962E-08  4.7676E-08  4.4444E-08  4.1799E-08  3.9525E-08  3.7531E-08  3.5756E-08  3.4154E-08  3.1356E-08
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LAYER   14
THE LINE PROFILE IS VOIGT
MULT   =    0.0          1.0000E-01  2.0000E-01  3.0000E-01  4.0000E-01  5.0000E-01  6.0000E-01  7.0000E-01  8.0000E-01  1.0000E+00
ATMTAU =       .69508       .65036       .62836       .61165       .59761       .58520       .57415       .56394       .55459       .53751
ATMRAD =    6.3351E-06  6.5037E-06  6.7066E-06  6.8021E-06  6.8832E-06  6.9546E-06  7.0192E-06  7.0767E-06  7.1294E-06  7.2236E-06


SURFACE EMISSIVITY =        .8000
 SURFACE TEMPERATURE =   300.0000
   SURF=    2.3422E-05  2.1935E-05  2.1206E-05  2.0650E-05  2.0182E-05  1.9771E-05  1.9399E-05  1.9060E-05  1.8747E-05  1.8176E-05

SURFACE EMISSIVITY =        .8000
 SURFACE TEMPERATURE =   296.0000
   SURF=    2.0413E-05  1.9117E-05  1.8480E-05  1.7995E-05  1.7587E-05  1.7229E-05  1.6904E-05  1.6610E-05  1.6337E-05  1.5843E-05

SURFACE EMISSIVITY =        .9000
 SURFACE TEMPERATURE =   300.0000
   SURF=    2.6064E-05  2.4431E-05  2.3616E-05  2.2996E-05  2.2475E-05  2.2017E-05  2.1604E-05  [illegible]  [illegible]  [illegible]

SURFACE EMISSIVITY =        .9000
 SURFACE TEMPERATURE =   296.0000
   SURF=    2.2729E-05  2.1290E-05  2.0580E-05  2.0040E-05  1.9586E-05  1.9187E-05  1.8827E-05  1.8498E-05  1.8194E-05  1.7649E-05


SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =        .8000
   SUN =    1.3485E-06  1.2053E-06  1.1389E-06  1.0882E-06  1.0459E-06  1.0092E-06  9.7631E-07  9.4640E-07  9.1906E-07  8.7018E-07

SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =        .9000
   SUN =    2.2475E-07  2.0089E-07  1.8982E-07  1.8136E-07  1.7432E-07  1.6821E-07  1.6272E-07  1.5775E-07  1.5318E-07  1.4503E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =        .8000
   SUN =    3.6847E-07  3.1153E-07  2.8579E-07  2.6636E-07  2.5046E-07  2.3681E-07  2.2484E-07  2.1418E-07  2.0456E-07  1.8777E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =        .9500
   SUN =    6.1412E-08  5.1922E-08  4.7637E-08  4.4393E-08  4.1744E-08  3.9468E-08  [illegible]  [illegible]  [illegible]  [illegible]
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LAYER   15
THE LINE PROFILE IS DOPPLER
MULT   =    0.0          1.0000E-01  2.0000E-01  3.0000E-01  4.0000E-01  5.0000E-01  6.0000E-01  7.0000E-01  9.0000E-01  1.0000E+00
ATMTAU =         .67443       .64963      .62759       .61084       .59677       .58441       .57327       .56316       .55377       .54504
ATMRAD =    5.3242E-06  6.5721E-06  6.6954E-06  6.7905E-06  6.8713E-06  6.9423E-06  7.0065E-06  7.0638E-06  7.1181E-06  7.2059E-06


SURFACE EMISSIVITY =      .8800
 SURFACE TEMPERATURE =   300.0000
   SURF=   2.3398E-05  2.1912E-05  2.1179E-05  2.0621E-05  2.0152E-05  1.9740E-05  1.9368E-05  1.9028E-05  1.8715E-05  1.8144E-05

SURFACE EMISSIVITY =      .8800
 SURFACE TEMPERATURE =   296.0000
   SURF=   2.0389E-05  1.9095E-05  1.8456E-05  1.7970E-05  1.7561E-05  1.7202E-05  1.6878E-05  1.6583E-05  1.6309E-05  1.5812E-05

SURFACE EMISSIVITY =      .9800
 SURFACE TEMPERATURE =   300.0000
   SURF=   2.6057E-05  2.4402E-05  2.3585E-05  2.2964E-05  2.2442E-05  2.1983E-05  2.1569E-05  2.1191E-05  2.0841E-05  2.0206E-05

SURFACE EMISSIVITY =      .9800
 SURFACE TEMPERATURE =   296.0000
   SURF=   2.2706E-05  2.1265E-05  2.0553E-05  2.0012E-05  1.9557E-05  1.9157E-05  1.8796E-05  1.8467E-05  1.8163E-05  1.7609E-05


SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =       .8800
   SUN =   1.3478E-06  1.2046E-06  1.1302E-06  1.0874E-06  1.0452E-06  1.0085E-06  9.7558E-07  9.4577E-07  9.1836E-07  8.6952E-07

SOLAR ZENITH ANGLE =  45.00 DEGREES
 SURFACE EMISSIVITY =       .9800
   SUN =   2.2464E-07  2.0077E-07  1.8970E-07  1.8123E-07  1.7419E-07  1.6804E-07  1.6260E-07  1.5763E-07  1.5306E-07  1.4492E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =       .8800
   SUN =   3.6838E-07  3.1142E-07  2.6568E-07  2.6626E-07  2.5037E-07  2.3672E-07  2.2475E-07  2.1410E-07  2.0448E-07  1.8769E-07

SOLAR ZENITH ANGLE =  75.00 DEGREES
 SURFACE EMISSIVITY =       .9800
   SUN =   6.1397E-08  5.1904E-08  4.7614E-08  4.4376E-08  4.1728E-08  3.9453E-08  3.7459E-08  3.5683E-08  3.4080E-08  3.1282E-08
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