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MRDA

A MEDIUM RESOLUTION DATA ANALYSIS CODE

FOR THE HP2100 COMPUTER

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This report describes the Medium Resolution Data Analysis Code (MRDA) which is a computer software code developed to run on the HP2100 mini-computer at the Air Force Geophysics Laboratory. The code calculates the atmosphere transmittance of radiation in the 1800 - 6000 cm^{-1} range. The code can be used for a variety of paths (horizontal, vertical, downward, to space, etc). The user has the option of using either the 1962 U.S. Standard Model atmosphere or radiosonde data. Because of size restriction on the HP2100, MRDA is divided into seven overlays. The spectral

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Abstract (Continued)

absorption coefficients, which are calculated from the AFGL compilation of molecular line parameters (HITRAN), are accessed from a data tape. The transmittance calculated for horizontal paths near sea level agree with those calculated with HITRAN, but MRDA tends to overestimate the absorption in the neighborhood of strongly absorbing lines. Some recommendations for further upgrading of the code are given.

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I INTRODUCTION

The task of generating the Medium Resolution Data Analysis (MRDA) code was undertaken to provide medium resolution predictions of atmospheric transmission and radiation. Equally important is the requirement that the software operate on the HP2100 minicomputer. This enables a direct convenient inclusion of atmospheric effects in the radiation studies being carried out at AFGL. MRDA is basically a combination of the high resolution code HITRAN[1] and the low resolution code LOWTRAN3.[2] The basic input-output structure of MRDA is similar to that of LOWTRAN3, with additions to improve its spectral resolution.

The MRDA code is now operational on the HP2100 mini-computer. Because of severe limitations on core size the code is divided into seven segments. The MRDA code correctly reproduces the spectral structure of atmospheric transmittance calculations when compared to results using HITRAN. However, MRDA tends to overestimate the absorption at higher altitudes in the spectral region near the center of a strongly absorbing line. The framework for calculating atmospheric radiation is built into the program, although these calculations are not done in the present version of MRDA.

Section II outlines the instruction format for using MRDA. In Section III a discussion of the organization of MRDA is presented along with examples of how various types of calculations are performed. Section IV discusses the capabilities of the code and its accuracy. A listing of the computer code is given in Appendix A, supplemented by a flow chart for each segment (Appendix B) and a definition of symbols (Appendix C). A listing of the program used to generate the absorption coefficients is in Appendix D.

---

(1) R. A. McClatchey et al., "AFCRL Atmospheric Absorption Line Parameters," AFCRL-TR-73-0096, January 1973. 762 904

(2) J. E. A. Sebly and R. A. McClatchey, "Atmospheric Transmittance from 0.25 to 28.5 μm: Computer Code LOWTRAN3," AFCRL-TR-0255, May 1975.
A017 234

II INSTRUCTION FOR USING MRDA

Since MRDA is very close to LOWTRAN3 in concept and operation, the inputs to the two programs are virtually identical. For this reason much of the description presented here is a paraphrase of the LOWTRAN3 operation instructions. The input medium for MRDA, instead of a card deck, is a disk JOB file. This file contains all the input information that would normally appear in the input card deck for LOWTRAN3 with a few changes. A listing of the JOB file (called MDATA) is shown in Figure 1. The many different atmospheric data contained in LOWTRAN3 are not used by MRDA. MRDA uses none of the spectral atmospheric data and, in order to conserve memory, uses only one model atmosphere. Presently, the file MDATA contains the 1962 U.S. Standard Model Atmosphere.

In general, it is only necessary to change the last four lines of the JOB file (referred to here as input lines 1-4) in order to run the program for a given problem. The formats for the last four input lines and their application will be discussed next. The user has the option of different paths (horizontal, slant, vertical, to space) and the option of reading in radiosonde data to replace the model atmosphere.

A. INPUT DATA AND FORMATS

The data necessary to specify a given problem are given on the last four lines of the JOB file. They are as follows:

Input Line 1	MODEL, IHAZE, ITYPE, LEN, JP, IM, NLDAT, IRAD	FORMAT (7I3)
Input Line 2	H1, H2, ANGLE, RANGE, BETA, VIS	FORMAT (6F 10.3)
Input Line 3	V1, V2, DV	FORMAT (3F 10.3)
Input Line 4	DVM	FORMAT (F 10.2)

Definitions of the above quantities will be discussed in Section B.

If the quantity MODEL given on input line 1 is set equal to 0 or 2 (which means meteorological data are used as input to the program), then the above card sequence (and format for input line 2) is changed. These cases will be described in Section C.

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```
MDATA  T=00004 IS ON CR00001 USING 00018 BLKS R=0078

0001   :JOB,MRDA
0002   :RU,MRDA
0003      6  34
0004    2.830E+03 1.245E+03 5.374E+02 2.257E+02 1.193E+02 8.992E+01 6.341
0005    6.073E+01 5.822E+01 5.679E+01 5.320E+01 5.589E+01 5.159E+01 5.052
0006    4.514E+01 4.460E+01 4.317E+01 3.636E+01 2.669E+01 1.935E+01 1.456
0007    8.831E+00 7.434E+00 2.239E+00 5.893E-01 1.551E-01 4.084E-02 1.078
0008    1.970E-08-0.
0009    1.379E+04 5.034E+03 1.845E+03 6.735E+02 2.454E+02
0010       0.0 1.013E+03 288.1    5.9E+00    5.4E-05
0011       1.0 8.986E+02 281.6    4.2E+00    5.4E-05
0012       2.0 7.950E+02 275.1    2.9E+00    5.4E-05
0013       3.0 7.012E+02 268.7    1.8E+00    5.0E-05
0014       4.0 6.166E+02 262.2    1.1E+00    4.6E-05
0015       5.0 5.405E+02 255.7    6.4E-01    4.6E-05
0016       6.0 4.722E+02 249.2    3.8E-01    4.5E-05
0017       7.0 4.111E+02 242.7    2.1E-01    4.9E-05
001        8.0 3.565E+02 236.2    1.2E-01    5.2E-05
00         9.0 3.080E+02 229.7    4.6E-02    7.1E-05
0020      10.0 2.650E+02 223.2    1.8E-02    9.0E-05
0021      11.0 2.270E+02 216.8    8.2E-03    1.3E-04
0022      12.0 1.940E+02 216.6    3.7E-03    1.6E-04
0023      13.0 1.658E+02 216.6    1.8E-03    1.7E-04
0024      14.0 1.417E+02 216.6    8.4E-04    1.9E-04
0025      15.0 1.211E+02 216.6    7.2E-04    2.1E-04
0026      16.0 1.035E+02 216.6    6.1E-04    2.4E-04
0027      17.0 8.850E+01 216.6    5.2E-04    2.8E-04
0028      18.0 7.565E+01 216.6    4.4E-04    3.2E-04
0029      19.0 6.467E+01 216.6    4.4E-04    3.5E-04
0030      20.0 5.529E+01 216.6    4.4E-04    3.8E-04
0031      21.0 4.729E+01 217.6    4.8E-04    3.8E-04
0032      22.0 4.047E+01 218.6    5.2E-04    3.9E-04
0033      23.0 3.467E+01 219.6    5.7E-04    3.8E-04
0034      24.0 2.972E+01 220.6    6.1E-04    3.6E-04
0035      25.0 2.549E+01 221.6    6.6E-04    3.4E-04
0036      30.0 1.197E+01 226.5    3.8E-04    2.0E-04
0037      35.0 4.746E+00 236.5    1.6E-04    1.1E-04
0038      40.0 2.871E+00 253.4    6.7E-05    4.9E-05
0039      45.0 1.491E+00 264.2    3.2E-05    1.7E-05
0040      50.0 7.978E-01 270.6    1.2E-05    4.0E-06
0041      70.0 5.520E-02 219.7    1.5E-07    8.6E-08
0042     100.0 3.008E-04 210.0    1.0E-09    4.3E-11
0043     99999.                   210.0
```

Figure 1. Example of the MRDA JOB File

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```
0044      .20 .28600 .09530   .25 .28000 .05660   .31 .26200 .02060   .34
0045      .49 .18500 .01050   .51 .17600 .01000   .63 .14600 .00914   .69
0046      .86 .10800 .01020  1.06 .08910 .01080  1.54 .05790 .00924  2.00
0047     2.50 .02660 .00369  2.70 .02670 .00988  3.00 .02240 .00487  3.20
0048     3.39 .02090 .00222  3.50 .02100 .00171  3.75 .01950 .00143  4.00
0049     4.50 .01670 .00248  5.50 .01360 .00295  6.00 .01190 .00360  6.50
0050     7.20 .01330 .00629  7.90 .00784 .00504  8.20 .00809 .00702  8.50
0051     8.70 .02190 .01180  9.00 .02380 .01310  9.20 .02350 .01430  9.50
0052    10.00 .01570 .00698 10.59 .01350 .00549 11.00 .01220 .00439 13.00
0053    14.80 .00827 .00464 15.00 .01010 .00691 17.20 .01100 .00607 18.50
0054    20.00 .01010 .00587 25.00 .00878 .00565 27.90 .00821 .00562 30.00
0055    2.93E-04 3.86E-04 5.09E-04 6.56E-04 8.85E-04 1.06E-03 1.31E-03 1.
0056    2.27E-03 2.73E-03 3.36E-03 3.95E-03 5.46E-03 7.19E-03 9.00E-03 1.
0057    1.36E-02 1.66E-02 1.96E-02 2.16E-02 2.36E-02 2.63E-02 2.90E-02 3.
0058    3.40E-02 3.66E-02 3.92E-02 4.26E-02 4.60E-02 4.95E-02 5.30E-02 5.
0059    6.00E-02 6.30E-02 6.60E-02 6.89E-02 7.18E-02 7.39E-02 7.60E-02 7.
0060    8.08E-02 8.39E-02 8.70E-02 9.13E-02 9.56E-02 1.08E-01 1.20E-01 1.
0061    1.52E-01 1.60E-01 1.69E-01 1.60E-01 1.51E-01 1.37E-01 1.23E-01 1.
0062    1.16E-01 1.14E-01 1.12E-01 1.12E-01 1.11E-01 1.11E-01 1.12E-01 1.
0063    1.13E-01 1.12E-01 1.09E-01 1.07E-01 1.02E-01 9.90E-02 9.50E-02 9.
0064    8.65E-02 8.20E-02 7.65E-02 7.05E-02 6.50E-02 6.10E-02 5.50E-02 4.
0065    4.50E-02 4.00E-02 3.75E-02 3.50E-02 3.10E-02 2.65E-02 2.50E-02 2.
0066    1.95E-02 1.75E-02 1.60E-02 1.40E-02 1.20E-02 1.05E-02 9.50E-03 9.
0067    8.00E-03 7.00E-03 6.50E-03 6.00E-03 5.50E-03 4.75E-03 4.00E-03 3.
0068    3.50E-03 3.00E-03 2.50E-03 2.25E-03 2.00E-03 1.85E-03 1.70E-03 1.
0069    1.50E-03 1.50E-03 1.54E-03 1.50E-03 1.47E-03 1.34E-03 1.25E-03 1.
0070    9.06E-04 7.53E-04 6.41E-04 5.09E-04 4.04E-04 3.36E-04 2.86E-04 2.
0071    1.94E-04 1.57E-04 1.31E-04 1.02E-04 8.07E-05
0072    0.23 .187 .147 .117 .097 .087 .10  .120 .147 .174 .20  .24  .28
0073     0  2  1     1
0074          5.0    1013.0     26.85      40.0                .5E-5
0075     2300.000  2310.000     5.000
0076         0.50
0077   :EOJ
```

Figure 1. (cont.) Example of the MRDA JOB File

B. BASIC INSTRUCTIONS

The various quantities to be specified on each of the four control cards are discussed in this section

1. Input Line 1 MODEL, IHAZE, ITYPE, LEN, JP, IM, NLDAT, IRAD

The parameter MODEL either selects the model atmosphere or specifies that meteorological data are to be used in place of the standard model. IHAZE specifies whether aerosol attenuation is to be included in the calculation or not. For any problem the atmospheric path must be specified as one of three types according to ITYPE and LEN. The rest of the quantities given on input line 1 (which can be left blank if not required) provide the user with options to suppress printing (JP), and to input a new model atmosphere (IM, NLDAT). The options for the above parameters and their uses are stated and described in detail below:

MODEL = 0 if meteorological data are specified (for horizontal paths only)*

= 1 selects 1962 US STANDARD Model Atmosphere

= 2 if a new model atmosphere (or radiosonde data) is to be instered.*

MRDA currently uses only the 1962 U.S. Standard Model atmosphere. If any of the other LOWTRAN3 model atmospheres are desired a new JOB file can be created with the appropriate model atmosphere in place of the U.S. Standard and setting MODEL = 1. MRDA will still identify the model as the 1962 U.S. Standard. Since MRDA assumes the earth's radius is 6371.23 km this may introduce minor differences when a model other than the U.S. Standard atmosphere is used.

IHAZE = 0 means no aerosol attenuation included in the calculations.

IHAZE = 1 or 2 if aerosol attenuation is required (see also Input Line 2).

If IHAZE is set equal to 1 or 2 and visual range (VIS) is not specified on Input Line 2, then the program will automatically select visual ranges of 23 km or 5 km, respectively.

* In these cases the format for Input Line 2 changes (see nonstandard conditions) Section C

ITYPE = 1 for a horizontal (constant pressure) path.

= 2 for a vertical or slant path between two altitudes.

= 3 for a vertical or slant path to space.

The TYPE 1 path should not be confused with a long 90^{o} path where the local height at the end of the trajectory is significantly different from the beginning height. In such a case, specify the path according to ITYPE = 2 (see Section B2)

LEN = 0 for normal operation of program.

LEN = 1 selects the downward TYPE 2 path shown in Figure 2(e).

The parameter LEN can be ignored (that is, left blank) for the majority of cases. It need only be used for a downward looking path (H2 > H1) when two paths are possible for the same input parameters. In such a case, a computer printout statement will be given indicating that the user has two choices for the problem and that the shorter path (see Figure 2(d)) has been executed. Set LEN = 1 for the longer case.

JP = 0 for normal operation of program.

JP = 1 to suppress printing of transmittance table

IM = 1 when radiosonde data are to be read in initially

IM = 0 for normal operation of program or when subsequent calculations are to be run with MODEL = 2

NLDAT = Number of levels to be read in for MODEL = 2

Note that IM and NLDAT are only used when MODEL = 2.

IRAD is a flag to indicate whether or not a radiation calculation is to be performed and is defined as indicated below.

IRAD = 1 perform radiation calculation.

IRAD = 0 do not perform radiation calculation.

Only the IRAD = 0 option should be used in the present version of MRDA! In the case of IRAD = 1 an additional input is required between the first and second input lines. This input is as follows:

EMISS, TBACK FORMAT (2F 10.3)

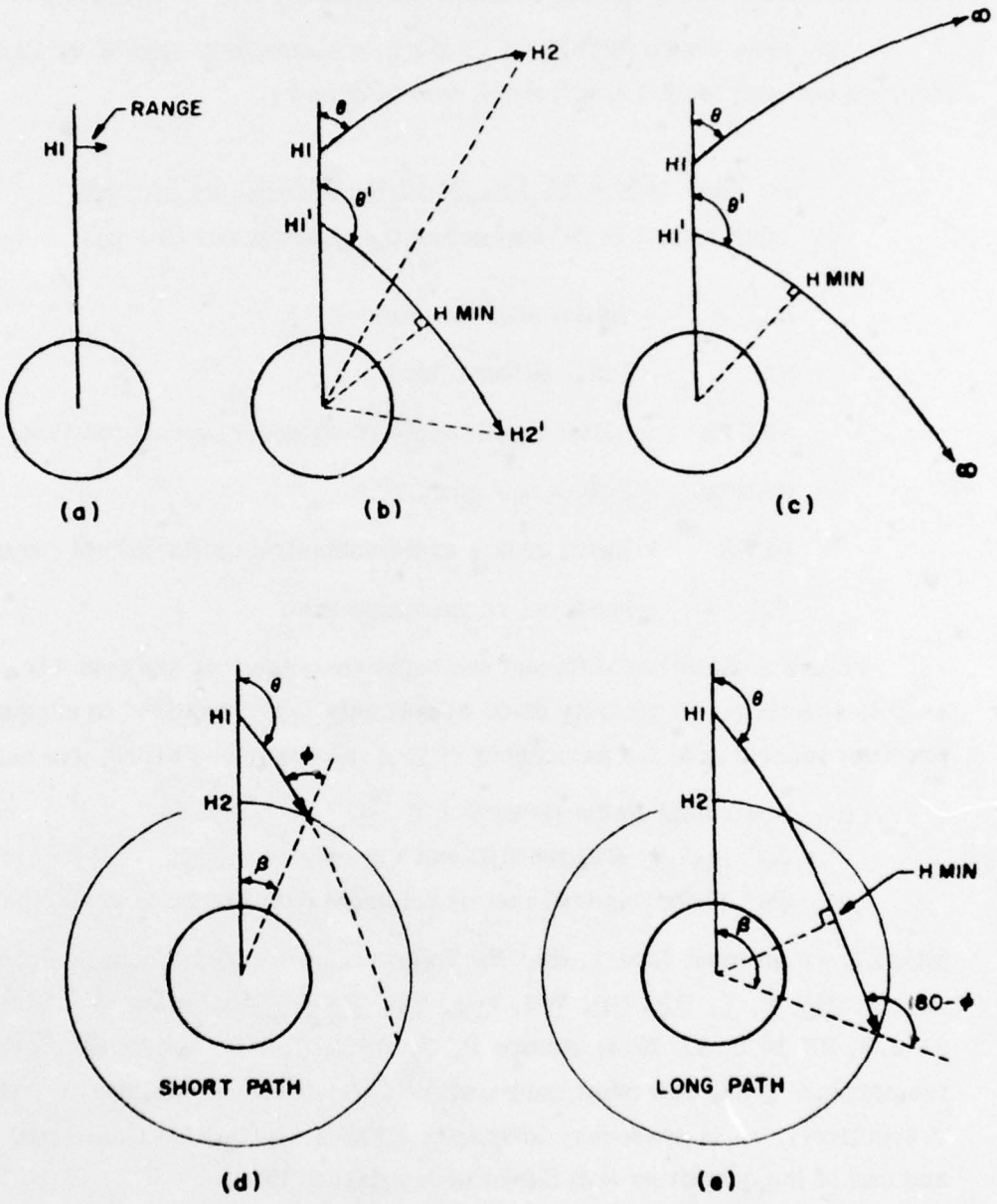


Figure 2. Geometrical Path Configuration for: (a) Horizontal Paths (Type 1), (b) Slant Paths Between Two Altitudes H1 and H2 (Type 2), and (c) Slant Paths to Space (Type 3). For downward looking paths where HMIN < H2 < H1, two trajectories are possible as indicated in (d) and (e). From Reference (2).

EMISS and TBACK define the emissivity and temperature of a background radiation source located at the beginning of the atmospheric path. TBACK is in units of ^{o}K.

In the case where MODEL = 2, the new atmosphere (model or radiosonde data) is inserted between Input Lines 1 and 2 (see Section C).

2. Input Line 2 H1, H2, ANGLE, RANGE, BETA, VIS

Input Line 2 is used to define the geometrical path parameters for a given problem.

H1 = Initial altitude (km)

H2 = Final altitude (km)

ANGLE = Initial zenith angle (degrees) as measured from H1

RANGE = Path length (km)

BETA = Earth centre angle subtended by H1 and H2 (degrees)

VIS = Sealevel visual range (km)

Figure 2 shows the different atmospheric paths that are possible. It is not necessary to specify every quantity given above; only those required to adequately describe the problem according to the parameter ITYPE (as described below) are needed.

(1) Horizontal Paths (ITYPE = 1)

(a) Specify H1, RANGE and VIS only

(b) If nonstandard meterorological data are to be used, that is, if

MODEL = 0 on Input Line 1, then the following parameters must be specified on Input Line 2: H1, P, T, DP, RH, WH, WO, VIS, RANGE according to FORMAT (3F 10.3, 2F 5.1, 2E 10.3, 2F 10.3), where P, T, DP, RH, WH, and WO are the pressure (mb), temperature (^{o}C), dew point temperature (^{o}C), relative humidity (%), H_2O density (gm m^{-3}), respectively. It is necessary to specify all of the quantities underlined with a full line and one of the quantities underlined with a dashed line.

(2) Slant Paths to Space (ITYPE = 3)

specify H1, ANGLE and VIS

(3) Slant Paths Between Two Altitudes (ITYPE = 2)

(a) Specify H1, H2, ANGLE, and VIS; or

(b) Specify H1, ANGLE, RANGE, and VIS; or

(c) Specify H1, H2, RANGE, and VIS.

For cases (b) and (c), the program will calculate H2 and ANGLE respectively, assuming no refraction and then proceed as for case (a). This method of defining the problem should be used when refraction effects are not important, e.g., for ranges of a few tens of km at zenith angles less than 80^{o}. It can also be used for larger angles (including 90^{o}) provided that the path lies within one atmospheric layer. Slant paths to space (ITYPE = 3) or between two altitudes (ITYPE = 2) in which both ANGLE and RANGE are not defined, are not possible in MRDA. In LOWTRAN3 these paths require the calculation of the initial zenith angle of the path by use of subroutine ANGLE. MRDA does not contain this routine; thus these paths are not allowed. If this case is attempted, an error message will be printed and execution halted.

In the case where MODEL = 2 the new model atmosphere (or radiosonde data) is inserted between Input Lines 1 and 2 (see Section C).

3. Input Line 3 V1, V2, DV

The spectral range over which transmittance data are required and the spectral increments at which the continuum calculations are to be made are given by:

V1 = initial frequency in wave numbers (cm^{-1})

V2 = final frequency in wave numbers (cm^{-1}) where V2 > V1

DV = frequency increment (or step size) (cm^{-1}) for continuum calculations.

(Note that $\nu = 10^{4}/\lambda$ where ν is the frequency in cm^{-1} and λ is the wavelength in microns, and that DV can only take on values which are a multiple of $5 cm^{-1}$.)

4. Input Line 4 DVM

The variable DVM defines the spectral steps at which the medium resolution calculations are done and the wavenumber interval of the final output. A value of 0.05 cm^{-1} should be used, because it agrees with the spectral resolution of the library tape.

C. ATMOSPHERIC MODEL

Three options are available if atmospheric transmittance calculations are required for nonstandard conditions. Here nonstandard refers to conditions other than those specified by the model atmosphere in MDATA. The three options enable the reader to insert:

(1) His own model atmosphere(s) in place of the standard model, provided that the data are in exactly the same format and are specified at the same altitudes as the latter. In this case the appropriate print statements in MRDA (that identify the atmospheric model used) must be changed correspondingly.

(2) An additional atmospheric model (MODEL=2), which can be in the form of radiosonde data. The data need not be specified at the same altitudes as in the standard models.

(3) Meteorological conditions for a given horizontal path calculation (MODEL = 0 case). This was discussed in Section B-2 and will not be repeated here.

The first of these options requires the most effort and needs no further discussion here.

1. Additional Atmospheric Model (MODEL = 2)

As stated in Section B-2, a new model atmosphere can be inserted between Input Line 1 and 2 provided the parameters MODEL and IM are set equal to 2 and 1 respectively on Input Line 1. The number of atmospheric levels to be inserted (NLDAT) must also be specified on Input Line 1. The appropriate meteorological parameters and format for the atmospheric data are given below.

Z, P, T, DP, RH, WH, WO, AHAZE (FORMAT (3F 10.3, 2F 5.1, 2E 10.3, 2F 10.3))
where

Z = altitude (km)
P = pressure
T = ambient temperature (^{o}C)
DP = dew point temperature (^{o}C)
RH = relative humidity (%)
WH = water vapor density (gm m^{-3})
WO = ozone density (gm m^{-3})
AHAZE = aerosol number density (cm^{-3})

Note that it is only necessary to specify those quantities underlined with a full line and either of the quantities underlined with the dashed line.

If the aerosol number density was not measured as a function of altitude and the reader wishes to include aerosol attenuation in the calculation, set IHAZE = 1 on Input Line 1. In this case MRDA will use the aerosol models already contained in the program and interpolate to give aerosol number density values at the same altitudes as the radiosonde (or new model atmosphere) data. The program will then look for a sea level visual range (VIS) to be specified on Input Line 2. If VIS is not specified, a 23 km sea level visual range will be assumed. If aerosol attenuation is not required, set IHAZE = 0 on Input Line 1 as before.

D. RUNNING MRDA

As already mentioned all the inputs for MRDA are contained within the JOB file MDATA. Before running MRDA the HP2100 system should be in the normal keyboard mode since the JOB file uses FMGR. To execute MRDA simply type

*RUN, JOB, MD, AT, A

Before actually running MRDA two things should be done. First mount the appropriate MRDA input tape containing the spectral extinction coefficients corresponding to the frequencies of interest on UNIT 0. Second, depending on the value of IRAD, MRDA uses 1 or 2 disk files (TRAN1 and TRAN2). If the previous MRDA run ended other than normally, one or both of these files may still exist in the directory and should be purged before running MRDA once again. The output from MRDA will appear on the line printer.

*Any JOB file with the structure of MDATA (possibly) containing a different model atmosphere could just as wil be used.

III MRDA DESCRIPTION

A. DESCRIPTION OF MRDA SOFTWARE

MRDA is designed to make medium resolution atmospheric transmission calculations in the range of 1800 to 6000 cm^{-1} over a wide variety of geometrical paths. These calculations are carried out within MRDA in three stages. The first part of the calculation consists of predicting the continuum transmissions (H_2O, N_2, molecular scattering) along with aerosol absorption for the chosen path and wavenumber interval. These calculations are carried out by what is essentially LOWTRAN3 with all the spectral calculations removed. In the process of computing the continuum results, intermediate values are saved for later use. For example the pressure, temperature and altitude of each layer in the geometric path are stored. In addition, if a radiation calculation is requested (IRAD = 1) the transmission through each layer is also stored in a disk file named TRAN1. Finally the atmospheric concentration of H_2O and O_3 in each layer along with the molecular density (of all gases) for the particular path through each layer is computed and saved.

In the second part of MRDA the medium resolution spectral calculations are performed. The atmospheric information needed to carry out these calculations have been transfered from part 1. Three magnetic tapes contain a complete library of extinction coefficients necessary to compute the medium resolution results. These tapes are generated using the high resolution transmission program (HITRAN). The tapes are organized in 10 cm^{-1} blocks over the 1800 to 6000 cm^{-1} range that MRDA operates. In each wavenumber block exctinction coefficients for 6 molecular species at 9 pressure-temperature points are defined at wavenumbers which depend on the structure of the absorption spectra for the particular species in that wavenumber block. For each species the wavenumbers were chosen so as to define the spectra by identifying the strongest lines in the region. The extinction coefficients are then calculated at the line center, points slightly removed from the line center and midway between adjacent strong lines.

Using the information from part 1, the library tape data, and possibly the disk file TRAN1, the program calculates the total spectral transmission for the geometric path and frequencies defined by the input. In order to obtain the extinction coefficient from the tape at the particular pressure, temperature and frequency required, the program performs linear interpolations over the pressure-temperature matrix defined on the tape and then over frequency. Once having calculated the total transmission at a particular

frequency, that frequency, the transmission and radiation results are written to a disk file TRAN2.

Part 3 of the MRDA software combines the continuum and medium resolution results The continuum results from part 1 are linearly interpolated to obtain transmission values at the medium resolution frequencies. Finally the total transmission is computed at the medium resolution frequencies and written to a disk file for later use.

B. PROGRAM ORGANIZATION

Structurally MRDA is composed of 7 separate software segments or overlays. As described in Section A the 7 segments can be combined into 3 well defined parts. Part 1 (modified LOWTRAN3) consists of segments 1 through 5. Part 2 is segment 6 and part 3 segment 7. A complete listing of all segments and subroutines is shown in Appendix A. Appendix B contains a segment by segment detailed logic flow diagram for MRDA. Appendix C has a description of the variables used in each segment.

To improve the readability and ease in following the logic with MRDA, a particular notational convention for indices has been followed throughout. This convention is outlined below:

Index variables

I - frequency index

L - atmospheric level number. 0 to NL

LL - layer number, numbered sequencially along the geometric path

K - species index

In addition many variables beginning with I, L, or K refer to quantities related to these indicies.

C. MRDA LIBRARY TAPES

The MRDA Library tapes contain the spectral absorption coefficients for the six atmospheric species which have significant absorption in the 1800 - 6000 cm^{-1} region. The species are: H_2O, CO_2, O_3, N_2O, CO and CH_4. The absorption coefficients are calculated at the selected (P, T, ν) points and then written onto a tape that is accessed by MRDA. The CDC6600 computer at AFGL was used to generate the MRDA tapes.

1. Choice of Spectral Absorption Coefficients

Because of the severe constraint on the amount of available storage on the HP2100, the data in the MRDA library tape are organized so as to define the absorption spectra for the species in as compact a form as possible. Thus nine pressure-temperature (P, T) points are used to describe the atmosphere, and the total number of wavenumbers points within each block is limited to 250.

The choice of the (P,T) points is based on the expected range of atmospheric (P, T) values. Figure 3 shows the (P, T) profile of the U.S. Standard Model Atmosphere, the estimated limits of (P, T) variability, and illustrative radiosonde data taken from several AFGL Teal Ruby Missions.[3] The heavy dots within the circles show the nine (P, T) points at which the spectral absorption coefficients are calculated. Pressure-temperature points for pressures below 100 mb are not included in the tape at this time due to the problems with the spectral structure of the transmittance at these higher altitudes.

A considerable savings in the total number of wavenumber points at which the spectral absorption coefficients must be stored is obtained by identifying the stronger spectral lines within each wavenumber block. When one or more of the species have no strong lines within a block, the absorption coefficients are calculated at only four points. After locating the strong peaks, the extinction coefficients are calculated at the peak, at points ± 0.05 cm^{-1} removed from the peak, and at a point half way between two adjacent peaks. The spectra from one strong line to the next are described by five points. Between these points the spectral absorption coefficients are obtained by linear interpolation.

---

3. B. Sandford, et al., "Aircraft Signatures in the Infrared 1.2 to 5.5 Micron Region," AFGL-TR-76-0133, Air Force Geophysics Laboratory (OPR), Hanscom AFB, Mass. 01731, (June, 1976)

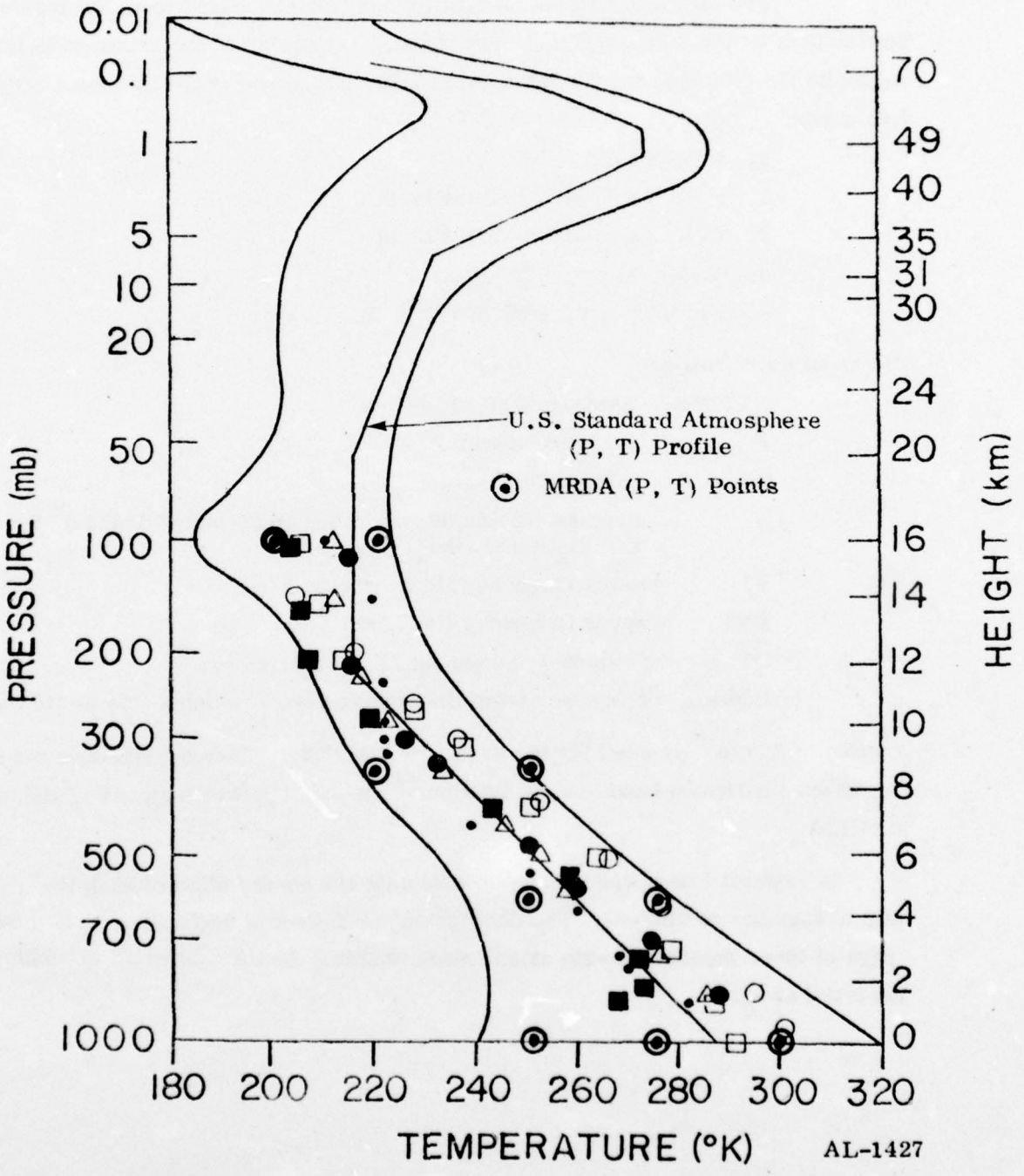


Figure 3 Temperature and pressure variations of the atmosphere. Radiosonde data from several Teal Ruby Missions are indicated. The outer lines indicate the approximate range of atmospheric temperature fluctuations. The center line is the U.S. Standard Atmosphere.

2. Calculation of the Spectral Absorption Coefficients

The spectral absorption coefficients are calculated from the molecular line parameters on the AFGL HITRAN Data Tape.[1] A listing of the program is given in Appendix D. The data for the input parameters are given by the following sequence of five cards:

1. NPTPTS (I2)
2. P (I), I = 1, NPTPTS (8E10.0)
3. T (I), I = 1, NPTPTS (8E10.0)
4. W (M), M = 1, 7 (7E10.3)
5. V1, VV2, DV, BOUND (6F10.3)

The input quantities are:

NPTPTS = number of (P, T) points

P = pressure values

T = temperature values

W = species column density = 0.269E20 molecules/cm^2 for (H_2O, CO_2, O_3, N_2O, CO, CH_4, O_2)

V1 = lower frequency limit, cm^{-1}

VV2 = upper frequency limit, cm^{-1}

DV = frequency increment, fixed at 0.05 cm^{-1}

BOUND = frequency from line center beyond which a line is not included, cm^{-1}

A value of 20 cm^{-1} is used for the parameter BOUND. Since oxygen does not have any important absorption bands below 6000 cm^{-1}, it is not included as one of the six species in MRDA.

A Lorentz line shape is used to calculate the contribution of each line to the spectral absorption coefficient. The absorption coefficient at each value ν_0 is a weighted average of three monochromatic calculations within a spectral interval of width 0.05 cm^{-1} centered at ν_0.

IV DISCUSSION

The atmospheric transmission code MRDA is operational on the HP2100 minicomputer. The software has been written in a format which allows the user considerable flexibility in his choice of atmospheric conditions and paths for transmittance calculations. In the regions with absorbing molecular lines, MRDA reproduces the correct spectral strucutre of the atmospheric transmittance and generally gives good quantitative predictions. However, as discussed below, values of the transmittance calculated by MRDA for atmospheric paths where the pressure is less than 600 mb is low in the immediate region of a strong absorbing line. This indicates that further study into improving the parameterization of the extinction coefficients at higher altitudes is needed. The structure of the HP2100 software code is designed with sufficient generality so that changes in the parameterization of the extinction coefficients are quite easily incorporated.

A. LOW RESOLUTION TRANSMITTANCE

The low resolution transmittance is calculated in the same manner as LOWTRAN3. Included are the contributions due to:

- 4μm H_2O continuum,
- 5μm N_2 continuum,
- Aerosol Scattering, and
- Molecular Scattering

Transmittance calculations by the MRDA code have been compared to those calculated by LOWTRAN3 and have been found to be in exact agreement.

B. ATMOSPHERIC PATHS

MRDA is designed to handle a variety of atmospheric paths:

- Paths to space, horizontal paths, and slant paths (upward or downward).

The identification and treatment of these paths are similar to those in LOWTRAN3. However, the high spectral resolution part of the calculation requires that the absorber amount for each atmospheric layer be considered, not just the total equivalent sea level absorber for the entire path. In MRDA, these absorber amounts are calculated in segments three,

four and five and stored in the matrix WW. They are passed on to segment six in the matrix WGAS. Because the concentrations of water vapor and ozone vary independently of the concentrations for the well mixed gases, they are also calculated and passed on in the matrices WH2O and WO3, respectively. These quantities are calculated and stored for all atmospheric paths.

C. HIGH RESOLUTION TRANSMITTANCE

The transmittance due to the spectral structure of absorption by the atmospheric gases is calculated in segment six. Basically, the calculation depends on two different inputs: the amount of an absorbing species along a segment of the path and the extinction coefficient for that species at the temperature and pressure of the segment. The total transmittance is then the product of the transmittances for all the segments. The results at each wavenumber are both printed out and stored on disk for later use.

For verification of the high resolution transmittance calculations, comparisons were made to calculations made using the HITRAN data tapes. The HITRAN calculations were done every 0.01 cm^{-1} and degraded to a resolution of 0.1 cm^{-1} by using a triangular slit function of half-width 0.1 cm^{-1}. Horizontal paths were used that had a constant amount of absorbing species (10^{20} molecules). The transmittance was calculated at several different temperatures and pressures in the spectral interval 2300-2310 cm^{-1}, which has strong CO_2 absorption.

At lower altitudes the agreement between transmittances calculated by HITRAN and MRDA was good. The regions of both strong and weak absorption were calculated properly by MRDA. The agreement was generally to within 10%; when the transmittance is very small (less than 0.10), the difference would become much larger. This is because the line shape in not sampled as extensively in MRDA as in HITRAN. As seen in Figure 4 MRDA reproduces the overall spectral structure of the transmittance calculated by HITRAN.

At higher altitude the agreement between MRDA and HITRAN is not as good because MRDA overestimates the absorption due to strong lines. Figure 5 shows the transmittance calculated by MRDA and HITRAN for a horizontal path at 500 mb pressure and 260°K temperature. Figure 6 shows a similar transmittance at 100 mb and 220°K. This indicates that further investigation into the calculation and storage of the spectral absorption coefficients is required. The initial choice of the extinction coefficients was determined by the requirement

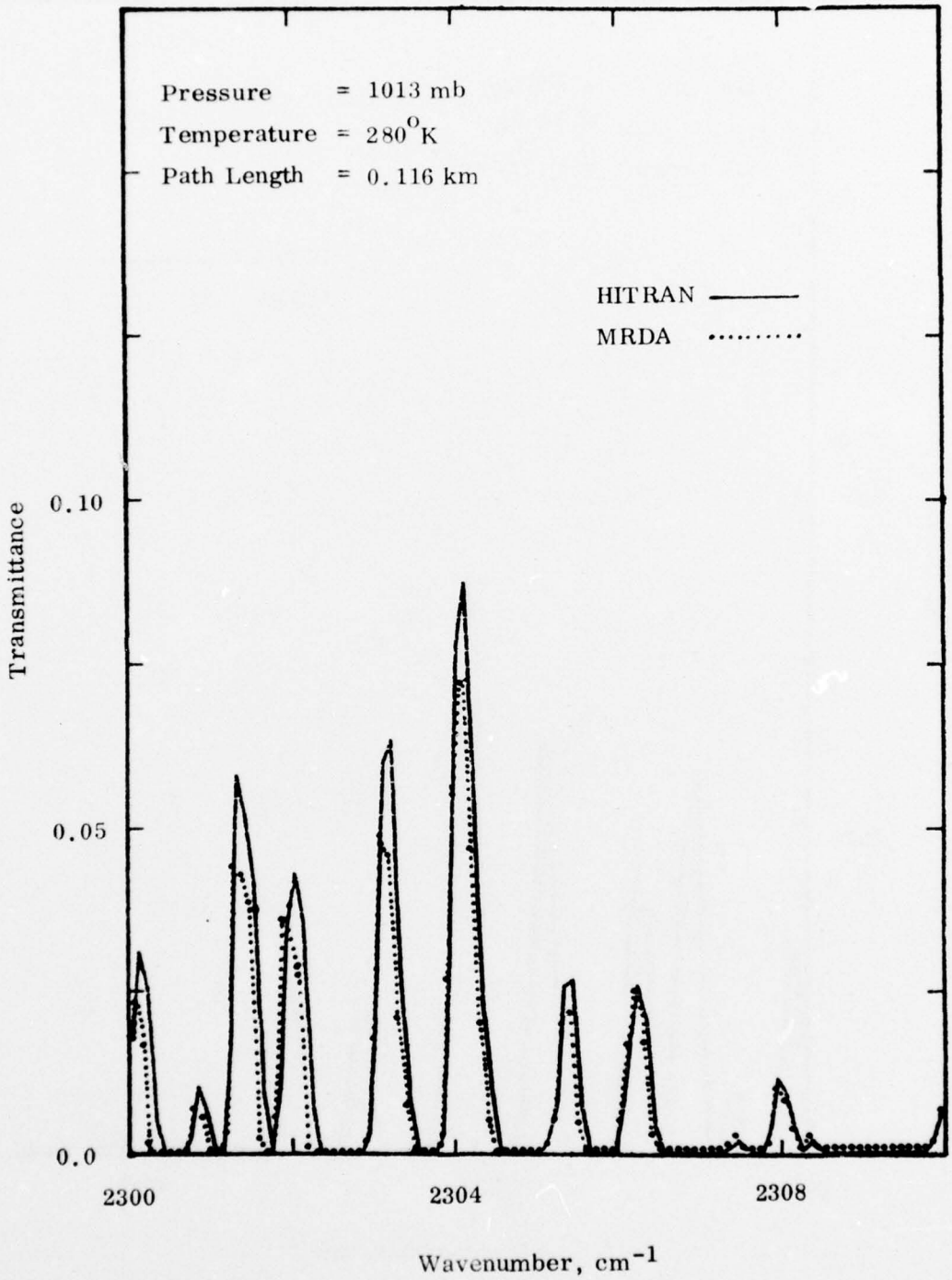


Figure 4. Comparison of MRDA and HITRAN Transmittance Calculations at 1013 mb Pressure

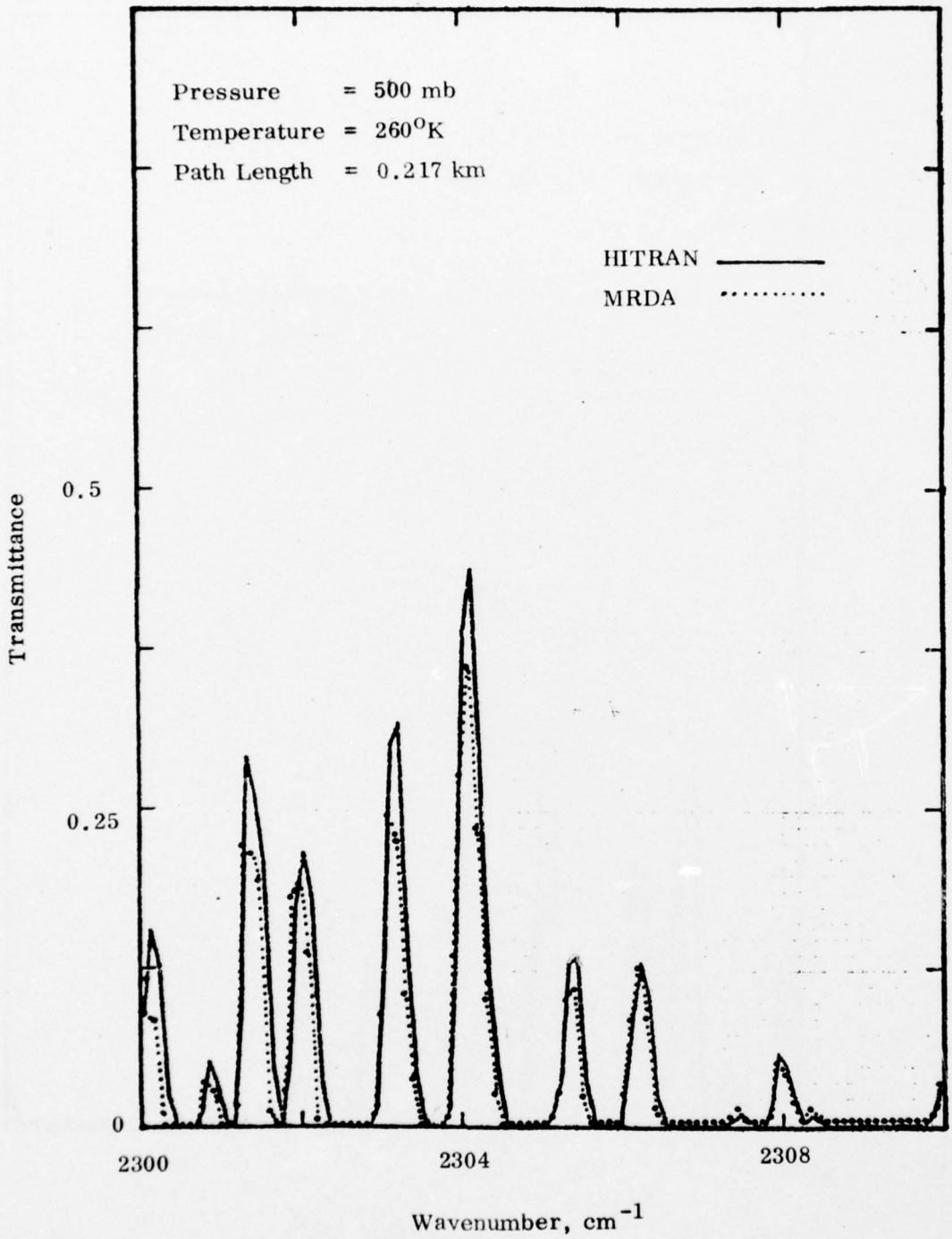


Figure 5. Comparison of MRDA and HITRAN Transmittance Calculations at 500 mb Pressure

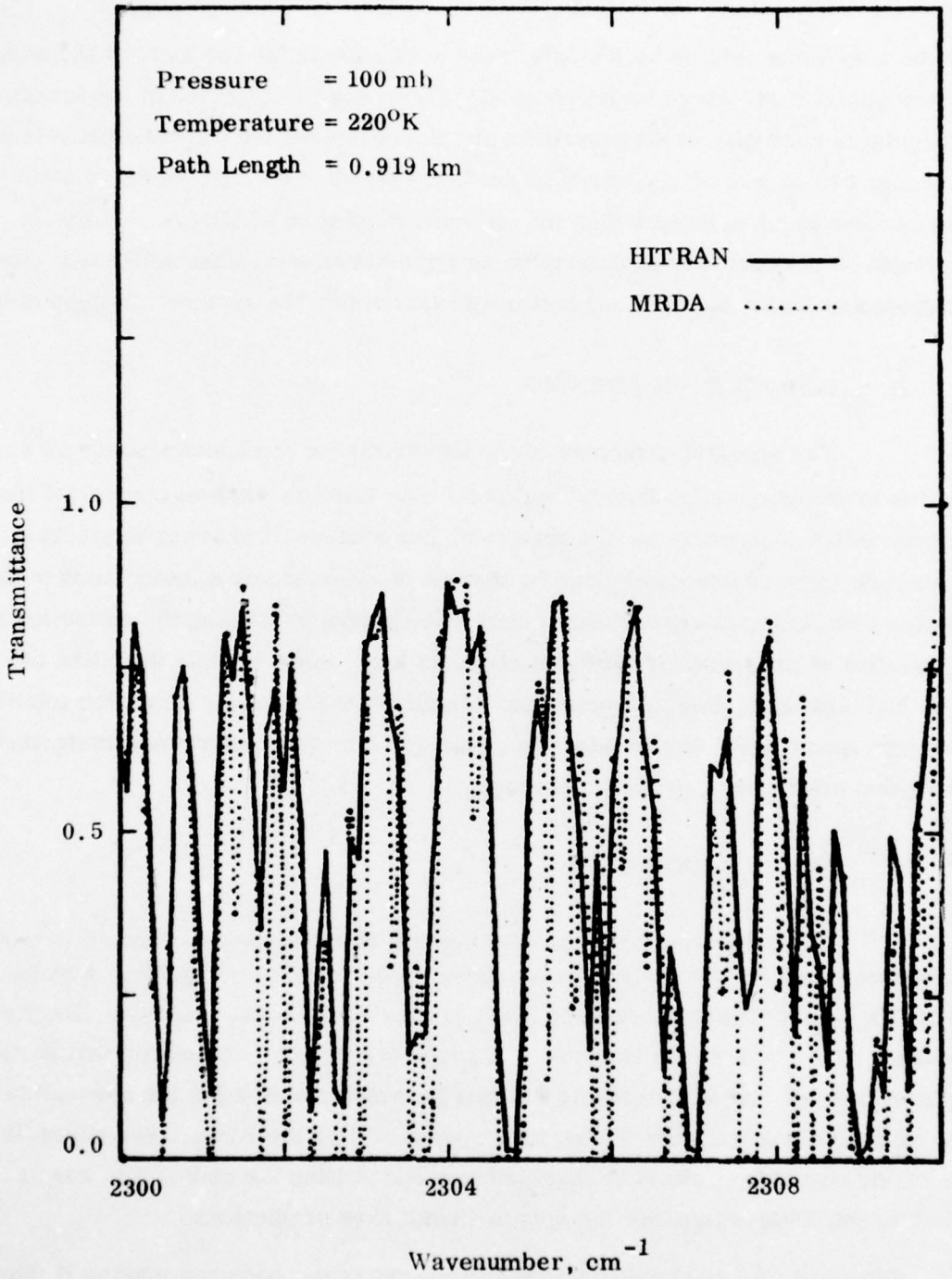


Figure 6. Comparison of MRDA and HITRAN Transmittance Calculations at 100 mb Pressure

that the number of entries on the data tapes not be too large and that, at the same time, the correct spectral structure be reproduced. The spectral structure of the transmittance is calculated correctly at all pressures and temperatures but the absorption is overestimated (by one or two orders of magnitude in some cases) when the full widths of strongly absorbing lines become much narrower than the intended resolution of MRDA, 0.1 cm^{-1}. Further investigation is necessary to determine an approximation scheme which will quantitatively parameterize these narrow lines better and stay within the size restrictions of the HP2100.

D. DOPPLER BROADENING

The spectral structure of the transmittance at altitudes above 18 km depends on Doppler broadening of the absorption lines. The Lorentz width of a spectral line decreases linearly with the pressure as one goes to higher altitudes and lower pressures. In this framework Doppler broadening can be thought of as providing a lower limit to the linewidth. Doppler broadening is approximated near line centers by making the extinction coefficient independent of pressure for altitudes above 18 km. Since the gas densities are very low at these high altitudes, this approximation should not significantly affect the total transmittance. However, quantitative verification must wait for a more accurate parameterization of the absorption coefficients on the MRDA tape.

E. RECOMMENDATIONS

The MRDA software code is capable of calculating the transmittance for a range of atmospheric paths. The code is operational on the HP2100 computer. Because of the HP2100's severe limitation on core size, it consists of seven overlays. As the quantitative accuracy of the code needs improvement, it is strongly recommended that further investigation be conducted to determine a better parameterization for the absorption coefficients. The difficulty in getting the MRDA code operational on the HP2100 has necessitated that the major contractual effort be directed towards writing the code. The result is that further effort is required to improve the code's quantitative predictions.

Some specific recommendations for upgrading the code and making it more flexible are listed below.

- Absorption Coefficients: Improve the parameterization of the absorption coefficients for pressures below 600 mb

- Radiation: Incorporate the calculation of atmospheric radiation. Most of the framework and the necessary parameters are already incorporated in the MRDA code
- Model Atmospheres: Increase the user's choice of model atmospheres from the US Standard to include the other five model atmospheres in LOWTRAN3.
- Input: Allow path description to be made through the teletype as well as input files.

APPENDIX A

LISTING OF MRDA

```
0001          FTN,L
0002          PROGRAM MRIDA (3,90)
0003          DIMENSION NAME(3)
0004          COMMON TEMP(40),PRES(40),V1,V2,DV,IRAD,LMAX,AHZ2(20)
0005          COMMON RANGE,WW(40,8)
0006          COMMON Z(34),P(34),T(34),EH(8,34),WH(34),M,NL,RE,CW,CO,PI
0007          COMMON WO(34),HZ1(34),HZ2(6),TX(10),VH(8),W(8),E(8)
0008          COMMON C4(133),C5(15),AHAZE(34),VX(45),C7(45)
0009          COMMON C7A(45),LYR(40),ALT(40),IPRM
0010          COMMON X1,X2,H1,H2,N,NP,NP1,NP2,TX1,TX2,YN,YN1,YN2
0011          COMMON L,JP,L1,L2,PS,TS,X,REF,IP,LBR,EV,TMP,K2,H,DS
0012          COMMON PSI,SPHI,THET,THETA,PHI,BET,BETA,SALP,SR
0013          COMMON HMIN,LL,HM,RX,CA,RN,LEN,SUMA,AB,ALAM
0014          COMMON IXY,VIS,IV1,IV2,IHAZE,ITYPE,ANGLE,FILL(1392)
0015          COMMON T1,T2,TMIN,P1,P2,PMIN
0016          DATA NAME/2HSE,2HGT,2H1 /
0017          IPRM = 1
0018          CALL EXEC(8,NAME)
0019          END

**  NO ERRORS**     PROGRAM = 00054       COMMON = 05533
```

```
0020          PROGRAM SEGT1 (5,90)
0021          DIMENSION NAME(3)
0022          COMMON TEMP(40),PRES(40),V1,V2,DV,IRAD,LMAX,AHZ2(20)
0023          COMMON RANGE,WW(40,8)
0024          COMMON Z(34),P(34),T(34),EH(8,34),WH(34),M,NL,RE,CW,CO,PI
0025          COMMON WO(34),HZ1(34),HZ2(6),TX(10),VH(8),W(8),E(8)
0026          COMMON C4(133),C5(15),AHAZE(34),VX(45),C7(45)
0027          COMMON C7A(45),LYR(40),ALT(40),IPRM
0028          COMMON X1,X2,H1,H2,N,NP,NP1,NP2,TX1,TX2,YN,YN1,YN2
0029          COMMON L,JP,L1,L2,PS,TS,X,REF,IP,LBR,EV,TMP,K2,H,DS
0030          COMMON PSI,SPHI,THET,THETA,PHI,BET,BETA,SALP,SR
0031          COMMON HMIN,LL,HM,RX,CA,RN,LEN,SUMA,AB,ALAM
0032          COMMON IXY,VIS,IV1,IV2,IHAZE,ITYPE,ANGLE,FILL(1391)
0033          COMMON MM,MODEL,T1,T2,TMIN,P1,P2,PMIN
0034          INTEGER HZ(2,2)
0035          DATA NAME/2HSE,2HGT,2H3 /
0036          DATA HZ(1,1)/2H23/,HZ(1,2)/2HKM/,HZ(2,1)/2H 5/,HZ(2,2)/2HKM/
0037    C*****************************************************************
0038    C     PROGRAM MRDA CALCULATES THE TRANSMITTANCE OF THE ATMOSPHERE
0039    C     FROM 1800 CM-1 TO 6000 CM-1 (1.54 TO 5.56 MICRONS) AT 0.05 CM-1
0040    C     SPECTRAL INTERVALS ON A LINEAR WAVENUMBER SCALE.
0041    C*****************************************************************
0042    C     CALCULATION DEFINED BY FOUR CARD SEQUENCE AT END OF JOB FILE
0043    C
0044    C   CARD 1 MODEL,IHAZE,ITYPE,LEN,JP,IM,NLDAT
0045    C   CARD 2 H1,H2,ANGLE,RANGE,BETA,VIS
0046    C   CARD 3 V1,V2,DV
0047    C   CARD 4 DVM
0048    C
0049    C     MODEL=1 SELECTS U.S. STANDARD MODEL ATMOSPHERE
0050    C     MODEL=0 FOR HORIZ. PATH WHEN METEOROL. DATA USED INSTEAD OF CARD 2
0051    C     READ H1,P(MB),T(DEG C),DEW PT.TEMP(DEG C),%REL HUMIDITY,H2O DENSIT
0052    C     (GM.CM-3), O3 DENSITY(GM.M-3), VIS(KM),RANGE(KM) WITH FORMAT 429.
0053    C     MODEL=2 WHEN NEW MODEL ATMOSPHERE(E.G. RADIOSONDE DATA) USED.
0054    C     DATA CARDS ARE READ IN BETWEEN CARDS 1 AND 2, AND SHOULD CONTAIN
0055    C     ALTITUDE(KM),PRESSURE,TEMP,DEW PT.TEMP,REL. HUMIDITY,H2O DENSITY,
0056    C     O3 DENSITY,AEROSOL NO. DENSITY(CM-3) ACCORDING TO FORMAT 429.
0057    C     NOTE THAT EITHER DEW PT. TEMP. OR REL. HUMIDITY CAN BE USED
0058    C
0059    C     IF IHAZE=0 NO AEROSOL SCATTERING IS COMPUTED
0060    C     IHAZE=1 IF AEROSOL ATTENUATION REQUIRED (THIS IS USED IN
0061    C     CONJUNCTION WITH VISUAL RANGE(SEE CARD 2))
0062    C     IHAZE=1 OR 2 ALSO GIVE AEROSOL ATTENUATION FOR 23 KM AND 5 KM VIS.
0063    C     HAZE MODELS RESPECTIVELY IF VIS=0 ON CARD 2
0064    C
0065    C     ITYPE=1,2 OR 3 INDICATES THE TYPE OF ATMOSPHERIC PATH
0066    C     ITYPE=3, VERTICAL OR SLANT PATH TO SPACE
0067    C     ITYPE=2, VERTICAL OR SLANT PATH BETWEEN TWO ALTITUDES
0068    C     ITYPE=1, CORRESPONDS TO A HORIZONTAL (CONSTANT PRESSURE) PATH
0069    C
0070    C     H1=OBSERVER ALTITUDE (KM)
0071    C     H2=SOURCE ALTITUDE (KM)
0072    C     ANGLE=ZENITH ANGLE AT H1 (DEGREES)
0073    C     RANGE=PATH LENGTH (KM)
0074    C     BETA=EARTH CENTRE ANGLE
0075    C     VIS=VISUAL RANGE AT SEA LEVEL (KM)
```

```
0076  C      (IF ITYPE=1 READ H1 AND RANGE  IF ITYPE=3 READ H1 AND ANGLE.
0077  C      IF ITYPE=2 READ H1 AND TWO OTHER PARAMETERS E.G. H2 AND ANGLE)
0078  C
0079  C      V1=INITIAL FREQUENCY (WAVENUMBER CM-1) INTEGER VALUE
0080  C      V2=FINAL FREQUENCY (WAVENUMBER CM-1) INTEGER VALUE
0081  C      DV=FREQUENCY INTERVALS AT WHICH TRANSMITTANCE IS PRINTED
0082  C      NOTE: DV MUST BE A MULTIPLE OF 5 CM-1
0083  C
0084  C      DVM=MEDIUM RESOLUTION FREQUENCY INTERVAL (USE 0.05 CM-1)
0085  C      IF (IRAD.NE.0) INSERT A CARD FOR EMISSIVITY AND TEMPERATURE
0086  C      OF A BACKGROUND BLACKBODY SOURCE, INSERT AFTER CARD 1.
0087  C      EMISS=ATMOSPHERIC EMISSITIVITY FOR RADIATION CALCULATIONS
0088  C      TBACK=BACKGROUND TEMPERAT.,USED FOR RADIATION CALCULATIONS
0089  C      IRAD =0 ATMOSPHERIC RADIATION NOT CALCULATED
0090  C           =1 ATMOSPHERIC RADIATION CALCULATED
0091  C      ** ONLY RUN PRESENT VERSION WITH IRAD =0 **
0092  C*****************************************************************
0093  C
0094        GO TO(12,2,200,300) IPRM
0095  12    IPRM = 1
0096        BET = 0.0
0097        BETA = 0.0
0098        IXY = 0
0099        READ (5,400) IATM,NL
0100        READ (5,401) (HZ1(L),L=1,34)
0101        READ (5,401) (HZ2(L),L=1,5)
0102        DO 1 I=1,NL
0103  1     READ (5,402) Z(I),P(I),T(I),WH(I),WO(I)
0104        READ (5,431) (VX(I),C7(I),C7A(I),I=1,44)
0105        READ (5,405) (C4(I),I=1,133)
0106        READ(5,404) (C5(I),I=1,15)
0107        PI=2.0*ASIN(1.0)
0108        CA=PI/180.
0109        IP=0
0110  2     CONTINUE
0111        RE=6371.23
0112  C     JP NE 0  SUPRESS PRINT
0113        READ (5,400) MODEL,IHAZE,ITYPE,LEN,JP,IM,NLDAT,IRAD
0114        WRITE(6,400) MODEL,IHAZE,ITYPE,LEN,JP,IM,NLDAT,IRAD
0115  200   M=MODEL
0116        IF(IRAD.EQ.0) GO TO 360
0117        READ(5,406) EMISS,TBACK
0118        WRITE(6,351) EMISS,TBACK
0119  351   FORMAT(//"BACKGROUND SOURCE:  EMISSIVITY=",F5.2,
0120       15X,"TEMPERATURE="F5.1,"  DEGREES KELVIN"//)
0121  360   IF(IXY.GT.3) GO TO 8
0122        IF(M.EQ.2.AND.IM.NE.0) GO TO 4
0123        IF(M.EQ.0) GO TO 4
0124  300   READ(5,406) H1,H2,ANGLE,RANGE,BETA,VIS
0125        WRITE(6,425) H1,H2,ANGLE,RANGE,BETA,VIS
0126        X1=RE+H1
0127        IF(ITYPE.EQ.3) GO TO 560
0128        IF(ITYPE.EQ.1) GO TO 8
0129        X2=RE+H2
0130        IF(RANGE.EQ.0) GO TO 5
0131        WRITE(6,428) H1,H2,ANGLE,RANGE,BETA,VIS
```

```
0132          IF(H2.EQ.0.AND.ANGLE.NE.0) GO TO 3
0133          ANGLE=ACOS(0.5*((H2-H1)*(1.+X2/X1)/RANGE-RANGE/X1))/CA
0134          GO TO 7
0135    3     X2=SQRT((X1/RANGE+RANGE/X1+2.0*COS(ANGLE*CA))*X1*RANGE)
0136          H2=X2-RE
0137          GO TO 7
0138    4     CONTINUE
0139          IF(NLDAT.LE.0)NLDAT=1
0140          DO 540 L=1,NLDAT
0141          AHAZE(L)=0.0
0142          IF(M.EQ.0)READ(5,429)H1,P(1),TMP,DP,RH,WH(L),WO(L),VIS,
0143         1RANGE
0144          IF(M.EQ.0)WRITE(6,430)H1,P(1),TMP,DP,RH,WH(L),WO(L),VIS,
0145         1RANGE
0146          IF(M.GT.0)READ(5,429)Z(L),P(L),TMP,DP,RH,WH(L),WO(L),
0147         1AHAZE(L)
0148          J=IFIX(Z(L)+1.0E-6)+1.
0149          IF(M.EQ.0)Z(L)=H1
0150          IF(Z(L).GE.25.0) J=(Z(L)-25.0)/5.0+26.
0151          IF(Z(L).GE.50.0) J=(Z(L)-50.0)/20.0+31.
0152          IF(Z(L).GE.70.0) J=(Z(L)-70.0)/30.0+32.
0153          IF(J.GT.33)J=33
0154          FAC=Z(L)-FLOAT(J-1)
0155          IF(J.LT.26) GO TO 500
0156          FAC=(Z(L)-5.0*FLOAT(J-26)-25.)/5.
0157          IF(J.GE.31) FAC=(Z(L)-50.0)/20.
0158          IF(J.GE.32) FAC=(Z(L)-70.0)/30.
0159          IF(FAC.GT.1.0) FAC=1.0
0160  500     K=J+1
0161          T(L)=TMP+273.15
0162          TT=273.15/T(L)
0163          IF(RH.LE.0.0) TT=273.15/(273.15+DP)
0164          IF(WH(L).LE.0.0) WH(L)=F(TT)
0165          IF(RH.GT.0.0) WH(L)=0.01*RH*WH(L)
0166          IF(Z(L).GE.5.0) GO TO 520
0167          IF(AHAZE(L).EQ.0.0)AHZ2(L)=HZ2(J)*(HZ2(K)/HZ2(J))**FAC
0168  520     IF(AHAZE(L).EQ.0.0)AHAZE(L)=HZ1(J)*(HZ1(K)/HZ1(J))**FAC
0169          IF(MODEL.EQ.0) GO TO 8
0170          IF(L.EQ.1)WRITE(6,441)
0171          WRITE(6,429)Z(L),P(L),TMP,DP,RH,WH(L),WO(L),AHAZE(L)
0172  540     CONTINUE
0173          IM=0
0174          NL=NLDAT
0175  C       NOTE THAT Z(L) MAY NOT CORRESPOND TO THE VALUES GIVEN FOR STANDARD
0176  C       MODEL ATMOSPHERE
0177          GO TO 300
0178  560     IF(RANGE.GT.0.0) GO TO 580
0179          IF(H2.GT.0.0.AND.H2.LT.H1) GO TO 16
0180          GO TO 8
0181  580     ITYPE=2
0182          BETA=ACOS(0.5*(RANGE*RANGE/(X1*X2)-X2/X1-X1/X2))/CA
0183  5       IF(BETA.EQ.0.) GO TO 6
0184          GO TO 16
0185  C       BET=CA*BETA
0186  C       X2=RE+H2
0187  C       ANGLE=ATAN(X2*SIN(BET)/(X2*COS(BET)-X1))/CA
```

```
0188  C      RANGE=X2*SIN(BET)/SIN(ANGLE*CA)
0189  C      BET=BETA
0190  C      GO TO 8
0191  6      RANGE=(X2/X1)**2-(SIN(ANGLE*CA))**2
0192         IF(RANGE.GE.0.0) RANGE=X1*(SQRT(RANGE)-ABS(COS(ANGLE*CA)))
0193  7      IF(ANGLE.NE.0..OR.ANGLE.NE.180.) BET=ASIN(RANGE*SIN(ANGLE*CA)/X2)
0194         IF(ANGLE.LT.0.) ANGLE=ANGLE+PI
0195         IF(RANGE.LT.0.0) RANGE=-RANGE
0196         BET=BET/CA
0197         WRITE(6,428) H1,H2,ANGLE,RANGE,BET,VIS
0198  8      CONTINUE
0199         SUMA=0.
0200         IF(IXY.LE.2) READ(5,406)V1,V2,DV
0201         IF(IXY.LE.2)WRITE(6,406)V1,V2,DV
0202         IF(ITYPE.EQ.1) WRITE(6,407) H1,RANGE
0203         IF(ITYPE.EQ.2) WRITE(6,408) H1,H2,ANGLE
0204         IF(ITYPE.EQ.3) WRITE(6,409) H1,ANGLE
0205         IF(MODEL.EQ.0) M=2
0206         IF(VIS.GT.0.0) WRITE(6,417)VIS
0207         IF(VIS.LT.2.0.AND.VIS.GT.0.0) WRITE(6,442)
0208         IF(M.EQ.1) WRITE(6,414) M
0209         IF(IHAZE.EQ.0) WRITE(6,426)
0210         IF(VIS.LE.0.0.AND.IHAZE.GT.0) WRITE(6,416)IHAZE,(HZ(IHAZE,L),L
0211        1=1,2)
0212         AVW=10000./V1
0213         ALAM=10000./V2
0214         WRITE(6,418) V1,V2,DV,ALAM,AVW
0215         AVW=0.5E-4*(V1+V2)
0216         AVW=AVW**2
0217         CO=77.46+.459*AVW
0218         CW=43.487-0.3473*AVW
0219  9      IF(JP.EQ.0) WRITE(6,427)
0220         IF(ITYPE.EQ.1) GO TO 15
0221         DO 11 K=1,8
0222         VH(K)=0.0
0223  11     CONTINUE
0224         BETA=0.0
0225         SR=0.0
0226         IP=0
0227  C
0228  C***** NOW DEFINE CONSTANT PRESSURE PATH QUANTITES EH(1-4)
0229  C
0230         Y=CA*ANGLE
0231         SPHI=SIN(Y)
0232         R1=(RE+H1)*SPHI
0233         IF(H1.GT.Z(NL)) GO TO 13
0234         GO TO 15
0235  13     X=(RE+Z(NL))/(RE+H1)
0236         IF(SPHI.GT.X) GO TO 14
0237         H1=Z(NL)
0238         L1=NL
0239         SPHI=SPHI/X
0240         ANGLE=180.0-ASIN(SPHI)/CA
0241         R1=(RE+H1)*SPHI
0242         GO TO 15
0243  14     HMIN=R1-RE
```

```
0244          WRITE(6,433) HMIN
0245          IPRM=2
0246          NAME(3) = 2H5
0247          CALL EXEC(8,NAME)
0248    15    CONTINUE
0249          NAME(3) = 2H2
0250          CALL EXEC(8,NAME)
0251          CALL MRDA
0252    16    WRITE(6,445)
0253          STOP
0254    400   FORMAT(8I3,F10.3)
0255    401   FORMAT(8E10.3)
0256    402   FORMAT(F6.1,E10.3,F6.1,2E10.3)
0257    404   FORMAT(15F5.2)
0258    405   FORMAT(8E9.2)
0259    406   FORMAT(7F10.3)
0260    407   FORMAT(//,28H HORIZONTAL PATH, ALTITUDE =,F7.3,11H KM,RANGE =,
0261          1F7.3,3H KM)
0262    408   FORMAT(//,"SLANT PATH BETWEEN ALTITUDES H1 AND H2 WHERE",/
0263          1,"H1 =",F7.3,8H KM H2 =,F7.3,18H KM,ZENITH ANGLE =,F7.3,
0264          28H DEGREES)
0265    409   FORMAT(//,39HSLANT PATH TO SPACE FROM ALTITUDE H1 =,F7.3,
0266          1"KM",/,"ZENITH ANGLE =",F7.3,8H DEGREES)
0267    414   FORMAT(/10X,18H MODEL ATMOSPHERE ,I1,21H = 1962 US STANDARD  )
0268    416   FORMAT(/10X,18H       HAZE MODEL ,I1,3H = ,2A2,13H VISUAL RANGE)
0269    417   FORMAT(/25X"HAZE MODEL  =",F5.1," KM VISUAL RANGE AT SEA LEVEL")
0270    418   FORMAT(/,20HFREQUENCY RANGE V1= ,F7.1,13H CM-1 TO V2= ,F7.1,
0271          15H CM-1,/,"FOR DV =",F6.1,8H CM-1  (,F6.2," - ",F5.2,"MICRONS)")
0272    426   FORMAT(/10X,"AEROSOL SCATTERING NOT COMPUTED,IHAZE-0")
0273    427   FORMAT(//////31X,20H HORIZONTAL PROFILES/)
0274    428   FORMAT(//"H1=",F7.3,"KM, H2=",F7.3,"KM, ANGLE=",F8.4,", GEOM. R"
0275          1"ANGE =",F7.2,"KM"/"BETA=",F8.5,"DEG., VIS=",F6.1//)
0276    429   FORMAT(3F10.3,2F5.1,2E10.3,2F10.3)
0277    430   FORMAT(10X,"INPUT METEOROLOGICAL DATA"/," Z=",F7.2," KM, P=",F7
0278          1.2," MB,T",F5.1," C, DEW PT.TEMP",F5.1," C, REL HUMIDITY=",F5.1,
0279          2" %"/"  H2O DENSITY=",1PE9.2," GM M-3,OZONE DENSITY=",E9.2," G
0280          3M-3"/"  VISUAL RANGE=",0PF6.1," KM,RANGE=",F10.3" KM ")
0281    431   FORMAT(4(F6.2,2F7.5))
0282    433   FORMAT(//"TRAJECTORY MISSES EARTHS ATMOSPHERE.",/,"CLOSEST DIS"
0283          1"TANCE OF APPROACH IS",F10.2,1X,/,1X,"END OF CALCULATION")
0284    441   FORMAT(//"MODEL ATMOSPHERE NO. 2",/ 4X,"Z (KM)",3X,"P (MB)",4X,
0285          1 "T (C) DEW PT %RH  H2O(GM.M-3) O3(GM.M-3) NO. DEN.")
0286    442   FORMAT(//"FOG CONDITIONS MAY EXIST AT SEA LEVEL FOR THIS VISUAL RI
0287          1NGE",/,"  IF SO THEN ASSUME THE TRANSMITTANCE DUE TO FOG IS GIVEN
0288          2BY"/" THE TRANSMITTANCE AT 0.55 MICRONS")
0289    425   FORMAT(10X,7F10.3)
0290    445   FORMAT(//"***ILLEGAL INPUT PARAMETERS FOR MRDA***"/
0291          1"***CALCULATIONS TERMINATED***")
0292          END

**  NO ERRORS**     PROGRAM = 02851       COMMON = 05533
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```
0001          FTN,L
0002          PROGRAM SEGT2 (5,90)
0003          DIMENSION NAME(3)
0004          COMMON TEMP(40),PRES(40),V1,V2,DV,IRAD,LMAX,AHZ2(20)
0005          COMMON RANGE,WW(40,8)
0006          COMMON Z(34),P(34),T(34),EH(8,34),WH(34),M,NL,RE,CW,CO,PI
0007          COMMON WO(34),HZ1(34),HZ2(6),TX(10),VH(8),W(8),E(8)
0008          COMMON C4(133),C5(15),AHAZE(34),VX(45),C7(45)
0009          COMMON C7A(45),LYR(40),ALT(40),IPRM
0010          COMMON X1,X2,H1,H2,N,NP,NP1,NP2,TX1,TX2,YN,YN1,YN2
0011          COMMON L,JP,L1,L2,PS,TS,X,REF,IP,LBR,EV,TMP,K2,H,DS
0012          COMMON PSI,SPHI,THET,THETA,PHI,BET,BETA,SALP,SR
0013          COMMON HMIN,LL,HM,RX,CA,RN,LEN,SUMA,AB,ALAM
0014          COMMON IXY,VIS,IV1,IV2,IHAZE,ITYPE,ANGLE,FILL(1391)
0015          COMMON MM,MODEL,T1,T2,TMIN,P1,P2,PMIN
0016          DATA NAME/2HSE,2HGT,2H3 /
0017          GO TO(15,19) IPRM
0018    15    DO 17 L=1,NL
0019          PS=P(L)/1013.0
0020          TS=273.15/T(L)
0021          X=PS*TS
0022          PT=PS*SQRT(TS)
0023          D=0.1*WH(L)
0024          EH(1,L)=0.8*PT*X
0025          PPW=4.56E-5*D*T(L)
0026          EH(2,L)=D*PPW*EXP(6.08*(296.0/T(L)-1.0))
0027          EH(8,L)=D*(PPW+0.12*(PS-PPW))*EXP(4.56*(296.0/T(L)-1.0))
0028          EH(5,L)=.125E-2*X*WH(L)
0029          EH(6,L)=.467E-3*X*WO(L)
0030          EH(3,L)=X
0031          HAZE=HZ1(L)
0032          IF(M.EQ.2) HAZE=AHAZE(L)
0033          IF(Z(L).GE.5.0) GO TO 150
0034           IF(M.EQ.2.AND.IHAZE.EQ.2) HAZE=HZ2(L)
0035          IF(IHAZE.EQ.2.AND.M.EQ.2)HAZE=AHZ2(L)
0036          IF(VIS.LE.0.0) GO TO 150
0037          IF(M.EQ.2)HAZE= 6.389*((HZ2(L)-HZ1(L))/VIS+HZ1(L)/5.0-HZ2(L)/23.0)
0038          IF (M.NE.2) GO TO 150
0039          HAZE=6.389*((AHZ2(L)-AHAZE(L))/VIS+AHAZE(L)/5.0-AHZ2(L)/23.0)
0040    150   IF(HAZE.LT.0.0) HAZE=0.0
0041          EH(4,L)=3.5336E-4*HAZE
0042          IF(M.EQ.2) EH(4,L)=HAZE/AHAZE(1)
0043          EH(7,L)=1.0
0044          REF=1.0E-6*(CO*X*1013.0/273.15-PPW*CW)
0045          IF (L.EQ.NL) GO TO 16
0046          IF(MODEL.EQ.0.AND.L.GE.1) GO TO 26
0047          T2=T(L+1)
0048          W2=WH(L+1)
0049          PPW=4.56E-6*W2*T2
0050          EH(7,L)=0.5*(REF+1.0E-6*(CO*P(L+1)/T2-PPW*CW))
0051    16    IF (L.EQ.NL) EH(7,L)=0.
0052          IF (H1.GE.Z(L)) L1=L
0053          IF(JP.EQ.0) WRITE(6,434) L,Z(L),(EH(K,L),K=1,8),REF
0054          EH(7,L)=EH(7,L)+1.0
0055     17   CONTINUE
0056    170   IP=-1
```

```
0057          IK=0
0058          X1=H1
0059          CALL POINT (H1,YN,L,NP1,TX,IP)
0060          T1 = TX(9)
0061          P1 = TX(10)
0062          L1=L
0063          TX1=TX(7)
0064          DO 18 K=1,8
0065    18    E(K)=TX(K)
0066          LBR = 0
0067          IF (ITYPE.EQ.1) GO TO 26
0068          IF (ITYPE.EQ.3) H2=Z(NL)
0069          IF (ANGLE.GT.90.0) GO TO 28
0070    19    IF (ANGLE.GT.90.0.AND.NP1.GT.0) L1=L1+1
0071          L2=NL
0072          IF (ITYPE.EQ.3) GO TO 20
0073          CALL POINT (H2,YN,L,NP,TX,IP)
0074          T2 = TX(9)
0075          P2 = TX(10)
0076          L2=L
0077          IF (NP.GT.0) L2=L2-1
0078          EH(8,L1)=E(8)
0079    20    DO 21 K=1,6
0080          EH(K,L1)=E(K)
0081          IF (ITYPE.EQ.3) GO TO 21
0082          EH(K,L2+1)=TX(K)
0083    21    CONTINUE
0084          IF(ITYPE.NE.3)EH(8,L2+1)=TX(8)
0085          IF (L1.EQ.L2) TX1=TX1+YN-EH(7,L1)
0086    C
0087    C***** NOW DEFINE VERTICAL PATH QUANTITIES VH(1-6)
0088    C
0089          IF (JP.EQ.0) WRITE(6,420)
0090          DO 25 L=L1,L2
0091          X1=Z(L)
0092          X2=Z(L+1)
0093          IF (L.EQ.L1) X1=H1
0094          IF (L.EQ.L2) X2=H2
0095          DZ=X2-X1
0096          IF (L.EQ.NL) DZ=Z(L)-Z(L-1)
0097          DS=DZ
0098    C
0099    C*****  UPWARD TRAJECTORY
0100    C
0101          RX=(RE+X1)/(RE+X2)
0102          THETA=ASIN(SPHI)/CA
0103          PHI=ASIN(SPHI*RX)/CA
0104          BET=THETA-PHI
0105          SALP=RX*SPHI
0106          IF (SPHI.GT.1.E-10) DS=(RE+X2)*SIN(BET*CA)/SPHI
0107          BETA=BETA+BET
0108          PSI=BETA+PHI-ANGLE
0109          PHI=180.-PHI
0110          SR=SR+DS
0111          LL = L-L1+LBR+1
0112          DO 244 K=1,8
```

```
0113          EV=DS*EH(K,L)
0114          IF (L.EQ.NL) GO TO 22
0115          IF (EH(K,L).EQ.0.0.OR.EH(K,L+1).EQ.0.0) GO TO 23
0116          IF (EH(K,L).EQ.EH(K,L+1)) GO TO 24
0117          EV=DS*(EH(K,L)-EH(K,L+1))/ALOG(EH(K,L)/EH(K,L+1))
0118          GO TO 24
0119    22    IF (EH(K,L).EQ.0.0) GO TO 23
0120          IF (EH(K,L-1).EQ.0.0) GO TO 23
0121          IF (EH(K,L).EQ.EH(K,L-1)) GO TO 24
0122          EV=EV/ALOG(EH(K,L-1)/EH(K,L))
0123          GO TO 24
0124    23    EV=0.
0125    24    VH(K)=VH(K)+EV
0126    C
0127    C***** UPWARD PATH---STORE PARAMETERS
0128    C
0129    244   WW(LL,K) = EV
0130          LYR(LL) = L
0131          ALT(LL) = X1
0132          TEMP(LL) = SQRT(T(L)*T(L+1))
0133          PRES(LL) = SQRT(P(L)*P(L+1))
0134          IF (JP.EQ.0) WRITE(6,435) L,X1,(VH(K),K=1,6),BETA,THETA,SR
0135          IF (L.GE.NL) GO TO 25
0136          IF (L+1.EQ.L2) EH(7,L+1)=YN
0137          IF (L.EQ.L1) EH(7,L)=TX1
0138          RN=EH(7,L+1)/EH(7,L)
0139          SPHI=SPHI*RX/RN
0140          IF (SALP.GE.RN) SPHI=SALP
0141    25    CONTINUE
0142          IPRM = 1
0143          GO TO 100
0144    26    IPRM = 2
0145          GO TO 100
0146    28    IPRM = 3
0147    100   NAME(3) = 2H3
0148          CALL EXEC(8,NAME)
0149          CALL MRDA
0150    420   FORMAT (///////25X,"VERTICAL PROFILES",/59X,"BETA   THETA"
0151         13X,"RANGE")
0152    434   FORMAT(I3,F5.1,9(E8.2))
0153    435   FORMAT (I3,F5.1,6E8.2,2F8.3,F6.1)
0154          END

**  NO ERRORS**     PROGRAM = 01831       COMMON = 05533
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```
0001          FTN,L
0002          PROGRAM SEGT3 (5,90)
0003          DIMENSION NAME(3)
0004          COMMON TEMP(40),PRES(40),V1,V2,DV,IRADN,LMAX,AHZ2(20)
0005          COMMON RANGE,WW(40,8)
0006          COMMON Z(34),P(34),T(34),EH(8,34),WH(34),M,NL,RE,CW,CO,PI
0007          COMMON WO(34),HZ1(34),HZ2(6),TX(10),VH(8),W(8),E(8)
0008          COMMON C4(133),C5(15),AHAZE(34),VX(45),C7(45)
0009          COMMON C7A(45),LYR(40),ALT(40),IPRM
0010          COMMON X1,X2,H1,H2,N,NP,NP1,NP2,TX1,TX2,YN,YN1,YN2
0011          COMMON L,JP,L1,L2,PS,TS,X,REF,IP,LBR,EV,TMP,K2,H,DS
0012          COMMON PSI,SPHI,THET,THETA,PHI,BET,BETA,SALP,SR
0013          COMMON HMIN,LL,HM,RX,CA,RN,LEN,SUMA,AB,ALAM
0014          COMMON IXY,VIS,IV1,IV2,IHAZE,ITYPE,ANGLE,FILL(1391)
0015          COMMON MM,MODEL,T1,T2,TMIN,P1,P2,PMIN
0016          DATA NAME /2HSE,2HGT,2H4 /
0017          GO TO (25,26,28,35) IPRM
0018    25    LBR = L2-L1+LBR+1
0019          IPRM = 4
0020          CALL EXEC(8,NAME)
0021    C
0022    C***** HORIZONTAL PATH
0023    C
0024    26    DO 27 K=1,8
0025          W(K)=RANGE*EH(K,1)
0026          IF (MODEL.GT.0) W(K)=RANGE*TX(K)
0027    27    WW(1,K) = W(K)
0028          LYR(1) = L1
0029          IF(MODEL.EQ.0) TEMP(1) = T(1)
0030          IF(MODEL.NE.0) TEMP(1) = T1
0031          IF(MODEL.EQ.0) PRES(1) = P(1)
0032          IF(MODEL.NE.0) PRES(1) = P1
0033          IF(MODEL.EQ.0) ALT(1) = Z(1)
0034          IF(MODEL.NE.0) ALT(1) = H1
0035          LBR = 1
0036          GO TO 49
0037    28    CONTINUE
0038    C
0039    C*****  DOWNWARD TRAJECTORY
0040    C
0041          K2=0
0042          IF (NP1.EQ.1) L1=L1-1
0043          L2=L1+1
0044          YN1=YN
0045          L0=L1+1
0046          IF (H2.GT.Z(L1+1).OR.H1.EQ.H2) GO TO 30
0047          IF (NP1.EQ.1.AND.H2.GE.Z(L1+1)) GO TO 30
0048          CALL POINT (H2,YN,L,NP2,TX,IP)
0049          T2 = TX(9)
0050          P2 = TX(10)
0051          DO 29 K=1,8
0052    29    W(K)=TX(K)
0053          TX2=TX(7)
0054          YN2=YN
0055          IF (H2.LT.H1) H=H2
0056          L2=L
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```
0057          IF (L1.EQ.L2) TX2=TX1+YN2-EH(7,L)
0058          IF (H2.GT.H1) TX1=TX2
0059          IF (L1.EQ.L2.AND.H2.LT.H1) YN1=TX2
0060    30    A0=(RE+H1)*SPHI+YN1
0061          IF (H2.GE.H1) YN2=YN1
0062          DO 31 L=1,L1
0063          HMIN=A0/EH(7,L)-RE
0064          IF (L.EQ.L1) HMIN=A0/YN1-RE
0065          LMIN=L
0066          IF (HMIN.LE.Z(L+1)) GO TO 32
0067    31    CONTINUE
0068    32    X=HMIN
0069          IF (HMIN.LE.0) GO TO 34
0070          CALL POINT (X,YN,L,NP,TX,IP)
0071          TMIN = TX(9)
0072          PMIN = TX(10)
0073          LMIN=L
0074          TX3=TX(7)
0075          IF (L2.EQ.L.OR.L1.EQ.L) TX3=YN2+TX(7)-EH(7,L)
0076          IF(TX3.LT.0.0)TX3=TX(7)
0077          IF (L1.EQ.L.AND.H2.GE.H1) GO TO 33
0078          HMIN=A0/TX3-RE
0079          IF (ABS(X-HMIN).GT.0.0001) GO TO 32
0080    33    IF (L1.EQ.L.AND.H2.GE.H1) YN1=TX3
0081          IF (L2.EQ.L.AND.L1.NE.L2) YN2=TX3
0082          IF (H2.GE.H1) TX2=TX3
0083          IF (H2.GE.H1) L2=L
0084          IF (H2.GE.H1.OR.H2.LT.HMIN) H=HMIN
0085          WRITE(6,436) HMIN
0086          IF(H2.LT.HMIN)L2=L
0087          IF (H2.LT.HMIN) WRITE(6,440) HMIN
0088          GO TO 35
0089    34    WRITE(6,436) HMIN
0090          IF (H2.LT.H1) GO TO 35
0091          IF (ITYPE.EQ.3.OR.H2.GE.H1) WRITE(6,437)
0092          ITYPE=2
0093          TX2=EH(7,1)
0094          LMIN=0
0095          L2=1
0096          H2=0.0
0097          H=0.0
0098    C
0099    C***** NOW DEFINE VERTICAL PATH QUANTITIES VH(1-4)
0100    C
0101    35    IF (JP.EQ.0) WRITE(6,420)
0102          L = L0
0103          LL = LBR
0104          DO 40 I=1,NL
0105          LL = LL+1
0106          L=L-1
0107          REF=EH(7,L)
0108          IF (I.EQ.1) REF=YN1
0109          IF (I.EQ.1.AND.K2.EQ.1) REF=YN2
0110          IF (L.EQ.L2.AND.K2.EQ.0) REF=TX2
0111          IF (I.NE.1) X1=Z(L+1)
0112          X2=Z(L)
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0113          IF (L.EQ.L2.AND.K2.EQ.0) X2=H
0114          IF (L.EQ.LMIN.AND.K2.EQ.1) X2=HMIN
0115          HM=(RE+X1)*SPHI-RE
0116          IF (HM.GT.Z(L).AND.HM.GT.X2) X2=HM
0117          RX=(RE+X1)/(RE+X2)
0118          DS=X1-X2
0119          ALP=90.0
0120          THET=ASIN(SPHI)/CA
0121          SALP=RX*SPHI
0122          IF (ABS(X2-HM).GT.1.0E-5) ALP=ASIN(SALP)/CA
0123          BET=ALP-THET
0124          IF (SPHI.GT.1.0E-10) DS=(RE+X2)*SIN(BET*CA)/SPHI
0125          THETA=180.0-THET
0126          BETA=BETA+BET
0127          PSI=BETA-ALP-ANGLE+180.0
0128          SR=SR+DS
0129          DO 399 K=1,8
0130          AL=EH(K,L)
0131          BL=EH(K,L+1)
0132          IF (L.EQ.L1) BL=E(K)
0133          IF (L.EQ.L2.AND.H2.LT.H1.AND.H2.GT.0.0) AL=W(K)
0134          IF (L.EQ.LMIN.AND.H2.GE.H1) AL=TX(K)
0135          IF (L.EQ.LMIN.AND.ABS(H2-HM).LT.1.0E-5) AL=TX(K)
0136          IF (K2.EQ.0) GO TO 36
0137          IF (L.EQ.L2) BL=W(K)
0138          IF (L.EQ.LMIN) AL=TX(K)
0139    36    IF (AL.EQ.0.0.OR.BL.EQ.0.0) GO TO 38
0140          IF (AL.EQ.BL) GO TO 37
0141          EV=DS*(AL-BL)/ALOG(AL/BL)
0142          GO TO 39
0143    37    EV=DS*AL
0144          GO TO 39
0145    38    EV=0.0
0146    39    VH(K)=VH(K)+EV
0147    C
0148    C***** DOWNWARD PATH---STORE PARAMETERS
0149    C
0150    399   WW(LL,K) = EV
0151          LBR = LL
0152          LYR(LL) = L
0153          ALT(LL) = X1
0154          TEMP(LL) = SQRT(T(L)*T(L+1))
0155          PRES(LL) = SQRT(P(L)*P(L+1))
0156          IF (JP.EQ.0) WRITE(6,435) L,X1,(VH(K),K=1,6),BETA,THETA,SR
0157          IF (L.EQ.L2.AND.H2.GE.H1) GO TO 45
0158          IF (L.EQ.LMIN.AND.K2.EQ.1) GO TO 43
0159          IF (L.NE.1) RN=REF/EH(7,L-1)
0160          IF (L.EQ.L2+1) RN=REF/TX2
0161          IF (L.EQ.L2.AND.K2.EQ.0) RN=REF/YN2
0162          IF (L.EQ.(LMIN+1).AND.K2.EQ.1) RN=REF/TX3
0163          IF (SALP.GE.RN) RN=1.0
0164          SPHI=SALP*RN
0165          IF (L.EQ.L2.AND.K2.EQ.0) GO TO 41
0166    40    CONTINUE
0167    41    IPRM = 1
0168          TEMP(LL) = SQRT(T2*T(L))
```

```
0169          PRES(LL) = SQRT(P2*P(L))
0170          GO TO 100
0171    43    IPRM = 2
0172          TEMP(LL) = SQRT(TMIN*T(L+1))
0173          PRES(LL) = SQRT(PMIN*P(L+1))
0174          GO TO 100
0175    45    IPRM = 3
0176          TEMP(LL) = SQRT(T1*T(L))
0177          PRES(LL) = SQRT(P2*P(L))
0178          GO TO 100
0179    49    IPRM = 5
0180   100    CALL EXEC(8, NAME)
0181          CALL MRDA
0182   420    FORMAT (///////25X,"VERTICAL PROFILES",/59X,"BETA   THETA"
0183         13X,"RANGE")
0184   435    FORMAT (I3,F5.1,6E8.2,2F8.3,F6.1)
0185   436    FORMAT (//"HMIN = ",F10.3)
0186   437    FORMAT (//"PATH INTERSECTS EARTH - PATH CHANGED TO TYPE 2 WITH H"
0187         1"2 = 0.0 KM")
0188   440    FORMAT (//"H2 WAS SET LESS THAN HMIN AND HAS BEEN RESET"/"EQUAL "
0189         1"TO HMIN I.E. H2 = ",F10.3)
0190          END

**  NO ERRORS**     PROGRAM = 01863       COMMON = 05533
```

```
0001          FTN,L
0002         . PROGRAM SEGT4 (5,90)
0003          DIMENSION NAME(3)
0004          COMMON TEMP(40),PRES(40),V1,V2,DV,IRAD,LMAX,AHZ2(20)
0005          COMMON RANGE,WW(40,8)
0006          COMMON Z(34),P(34),T(34),EH(8,34),WH(34),M,NL,RE,CW,CO,PI
0007          COMMON WO(34),HZ1(34),HZ2(6),TX(10),VH(8),W(8),E(8)
0008          COMMON C4(133),C5(15),AHAZE(34),VX(45),C7(45)
0009          COMMON C7A(45),LYR(40),ALT(40),IPRM
0010          COMMON X1,X2,H1,H2,N,NP,NP1,NP2,TX1,TX2,YN,YN1,YN2
0011          COMMON L,JP,L1,L2,PS,TS,X,REF,IP,LBR,EV,TMP,K2,H,DS
0012          COMMON PSI,SPHI,THET,THETA,PHI,BET,BETA,SALP,SR
0013          COMMON HMIN,LL,HM,RX,CA,RN,LEN,SUMA,AB,ALAM
0014          COMMON IXY,VIS,IV1,IV2,IHAZE,ITYPE,ANGLE,FILL(1392)
0015          COMMON T1,T2,TMIN,P1,P2,PMIN
0016          DATA NAME /2HSE,2HGT,2H5 /
0017          GO TO (41,43,45,47,49) IPRM
0018    41    IF (HMIN.LE.0) GO TO 47
0019          IF (LEN.EQ.0) WRITE(6,438)
0020          IF (LEN.EQ.0) GO TO 47
0021          IF (LEN.EQ.1) WRITE(6,439)
0022          K2=1
0023          X1=X2
0024          IF (ABS(X1-HMIN).LE.0.001) GO TO 47
0025          H=HMIN
0026          L=L2+1
0027          IF (NP2.EQ.1) L=L-1
0028          B=BETA
0029          PH=180.0-ASIN(SPHI)/CA
0030          TS=SR
0031          PS=PSI
0032          DO 42 K=1,8
0033    42    E(K)=VH(K)
0034          LSTORE = LBR
0035          GO TO 35
0036    43    BETA=2.*BETA-B
0037          PSI=2.*PSI-PS
0038          SR=2.*SR-TS
0039    C      LONG PATH  TAKEN
0040          PHI=PH
0041          DO 44 K=1,8
0042    44    VH(K)=2.*VH(K)-E(K)
0043    C
0044    C***** DOWNWARD H2.GT.H1--LONG PATH STORAGE
0045    C
0046          LLMIN = LBR+1
0047          LBR = 2*LBR-LSTORE
0048          DO 446 LL=LLMIN,LBR
0049          LMAP = LBR - LL + LSTORE
0050          ALT(LL) = ALT(LMAP+2)
0051          IF(LL.EQ.LLMIN) GO TO 442
0052          TEMP(LL) = SQRT(T(LMAP+1)*T(LMAP+2))
0053          PRES(LL) = SQRT(P(LMAP+1)*P(LMAP+2))
0054          GO TO 444
0055    442   ALT(LL) = HMIN
0056          PRES(LL) = SQRT(PMIN*P(LMAP+2))
```

```
0057          TEMP(LL) = SQRT(TMIN*T(LMAP+2))
0058    444   CONTINUE
0059          DO 446 K=1,6
0060    446   WW(LL,K) = WW(LMAP+1,K)
0061          GO TO 47
0062    45    DO 46 K=1,8
0063    46    VH(K)=2.0*VH(K)
0064    C
0065    C***** DOWNWARD H1.LT.H2---H1.NE.HMIN
0066    C
0067          LLMIN = LBR+1
0068          LBR = 2*LBR
0069          DO 468 LL=LLMIN,LBR
0070          LMAP = LBR-LL
0071          ALT(LL) = ALT(LMAP+2)
0072          IF(LL.EQ.LLMIN) GO TO 464
0073          TEMP(LL) = SQRT(T(LMAP+1)*T(LMAP+2))
0074          PRES(LL) = SQRT(P(LMAP+1)*P(LMAP+2))
0075          GO TO 466
0076    464   ALT(LL) = HMIN
0077          TEMP(LL) = SQRT(TMIN*T(LMAP+2))
0078          PRES(LL) = SQRT(PMIN*P(LMAP+2))
0079    466   LYR(LL) = LYR(LMAP+1)
0080          DO 468 K=1,6
0081    468   WW(LL,K) = WW(LMAP+1,K)
0082          BETA=2.0*BETA
0083          SR=2.0*SR
0084          IF (H2.EQ.H1) GO TO 47
0085          RN=TX1/YN1
0086          SPHI=SIN(ANGLE*CA)
0087          IF (SPHI.LT.RN) SPHI=SPHI/RN
0088          GO TO 19
0089    47    CONTINUE
0090          WRITE(6,406) HM
0091          DO 48 K=1,8
0092          W(K)=VH(K)
0093    48    CONTINUE
0094    49    WRITE (6,419)
0095          WRITE(6,421) (W(K),K=1,4),W(8)
0096          I=1
0097          L=1
0098          IV1=V1/5.0
0099          IF(V2.GT.32767.) V2=32767.
0100          IV2=V2/5.+.998
0101          IV1=5*IV1
0102          IV2=5*IV2
0103          IF (IV1.LT.350) IV1=350
0104          IF (DV.LT.5.) DV=5.
0105          NAME(3) = 2H5
0106          GO TO 100
0107    35    IPRM = 4
0108          NAME(3) = 2H3
0109          GO TO 100
0110    19    IPRM = 2
0111          NAME(3) = 2H2
0112    100   CALL EXEC(8,NAME)
```

```
0113          CALL MRDA
0114    406   FORMAT(7F10.3)
0115    419   FORMAT (/16X,38H EQUILAVENT SEA LEVEL ABSORBER AMOUNTS//
0116         17X"   NITROGEN (CONT)  H2O (CONT)     MOL  SCAT      AEROSOL,"/
0117         27X"          KM          GM CM-2          KM              KM"/)
0118    421   FORMAT (8H W(1-4)=4(E14.3)/ 22X,E14.3/)
0119    438   FORMAT(//"CHOICE OF TWO PATHS FOR THIS CASE -SHORTEST PATH TAKE"
0120         1"N."/"FOR LONGER PATH SET LEN=1.")
0121    439   FORMAT(///1X,"LL",3X,"LEVEL",2X,"ALTITUDE   TEMP",6X,"PRES",
0122         17X,"WH2O",7X,"WO3",8X"WGAS"/)
0123    500   FORMAT(/"DISK I/O ERROR, IERR =",I3)
0124          END

**  NO ERRORS**     PROGRAM = 01066       COMMON = 05533
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```
0001          FTN,L
0002          PROGRAM SEGT5 (5,90)
0003          DIMENSION TRAN1(41),IDCB(144),ISIZE(2),NAM1(3)
0004          DIMENSION NAME(3),TAU(21),WH2O(40),WO3(40),WGAS(40)
0005          COMMON TEMP(40),PRES(40),V1,V2,DV,IRAD,LMAX,AHZ2(20)
0006          COMMON RANGE,WW(40,8)
0007          COMMON Z(34),P(34),T(34),EH(8,34),WH(34),M,NL,RE,CW,CO,PI
0008          COMMON WO(34),HZ1(34),HZ2(6),TX(10),VH(8),W(8),E(8)
0009          COMMON C4(133),C5(15),AHAZE(34),VX(45),C7(45)
0010          COMMON C7A(45),LYR(40),ALT(40),IFRM
0011          COMMON X1,X2,H1,H2,N,NP,NP1,NP2,TX1,TX2,YN,YN1,YN2
0012          COMMON L,JP,L1,L2,PS,TS,X,REF,IP,LBR,EV,TMP,K2,H,DS
0013          COMMON PSI,SPHI,THET,THETA,PHI,BET,BETA,SALP,SR
0014          COMMON HMIN,LL,HM,RX,CA,RN,LEN,SUMA,AB,ALAM
0015          COMMON IXY,VIS,IV1,IV2,IHAZE,ITYPE,ANGLE,FILL(1392)
0016          COMMON T1,T2,TMIN,P1,P2,PMIN
0017          EQUIVALENCE (TAU,AHZ2),(WH2O,WW(1,1)),(WO3,WW(1,2))
0018          EQUIVALENCE (WGAS,WW(1,3))
0019          DATA NAME /2HSE,2HGT,2H5 /,NAM1/2HTR,2HAN,2H1  /
0020    C
0021    C***** BEGINNING OF TRANSMITTANCE CALCULATIONS
0022    C
0023          ISIZE(1) = 150
0024          IF(IRAD.NE.0) CALL CREAT(IDCB,IERR,NAM1,ISIZE,3)
0025          IF(IERR.EQ.-1) GO TO 110
0026          IDV = DV
0027          IV = IV1-IDV
0028          LMAX = LBR
0029          LOOP = 1
0030          INDEX = 0
0031          IF(IRAD.EQ.1) LOOP = LBR
0032    50    IV = IV+IDV
0033          INDEX=INDEX+1
0034          IF(INDEX.NE.1) GO TO 52
0035          IF(JP.NE.0) GO TO 52
0036          WRITE(6,422)
0037    52    CONTINUE
0038          DO 95 LL=1,LOOP
0039          DO 53 K=1,8
0040          W(K) = VH(K)
0041          IF(LL.GT.1) W(K) = W(K)-WW(LL-1,K)
0042          TX(K) = 0.0
0043    53    CONTINUE
0044          TX(1) = 1.0
0045          ICOUNT=ICOUNT+1
0046          SUM=0.0
0047          V=IV
0048          I=(IV-350)/5+1
0049          IF(IV.LT.670) GO TO 72
0050          IF(IV.LE.3000) GO TO 61
0051    C
0052    C*****   MOLECULAR SCATTERING
0053    C
0054          C6=9.807E-20*(V**4.0117)
0055          TX(3)=C6*W(3)
0056          SUM=SUM+TX(3)
```

```
0057          IF (IV.LT.13000) GO TO 72
0058    C
0059    C*****  WATER VAPOR CONTINUUM 10 MICRON REGION
0060    C
0061      61  IF(IV.GT.1350) GO TO 62
0062          TX(2)=(4.18+5578.0*EXP(-7.87E-3*V))*W(2)
0063          GO TO 66
0064      62  IF(IV.LT.2350) GO TO 68
0065    C
0066    C*****  WATER VAPOR CONTINUUM 4 MICRON REGION
0067    C
0068          XI=(V-2350.0)/50.0+1.0
0069          DO 63 NH=1,15
0070          XH=XI-FLOAT(NH)
0071          TX(2)=C5(NH)
0072          IF(XH) 64,65,63
0073      63  CONTINUE
0074     64   TX(2)=TX(2)+XH*(C5(NH)-C5(NH-1))
0075      65  TX(2)=TX(2)*W(8)
0076      66  SUM=SUM+TX(2)
0077          IF(IV.LE.1350.OR.IV.GT.2740) GO TO 72
0078    C
0079    C*****    NITROGEN CONTINUUM
0080    C
0081    68    IF (IV.LT.2080) GO TO 72
0082          K4=I-346
0083          TX(1)=C4(K4)*W(1)
0084          SUM=SUM+TX(1)
0085    C
0086    C*****    AEROSOL EXTINCTION
0087    C
0088    72    ALAM=1.0E+4/V
0089          XX=0.0
0090          YY=0.0
0091          IF (IHAZE.EQ.0.) GO TO 90
0092          DO 88 N=1,44
0093          XD=ALAM-VX(N)
0094          IF(XD)89,88,88
0095      88  CONTINUE
0096      89  XX=(C7(N)-C7(N-1))*XD/(VX(N)-VX(N-1))+C7(N)
0097          YY=(C7A(N)-C7A(N-1))*XD/(VX(N)-VX(N-1))+C7A(N)
0098       90 TX(8)=YY*W(4)
0099          TX(4)=XX*W(4)
0100          SUM=SUM+TX(4)
0101          TX(7)=SUM
0102          DO 94 K=1,8
0103          IF (TX(K).EQ.0.0) GO TO 92
0104          IF (TX(K).GT.20.) GO TO 93
0105          TX(K)=EXP(-TX(K))
0106          GO TO 94
0107    92    TX(K)=1.0
0108          GO TO 94
0109    93    TX(K)=0.
0110    94    CONTINUE
0111          TX(8)=1.0-TX(8)
0112          AB=1.-TX(7)
```

```
0113          IF(IV.EQ.IV1.OR.IV.EQ.IV2) AB=0.5*AB
0114          SUMA=SUMA+AB*DV
0115          IF(JP.EQ.0.AND.LL.EQ.1) WRITE(6,423) IV,ALAM,TX(7),(TX(K),
0116         1K=1,4),TX(8),SUMA
0117          IF(IRAD.NE.0) TRAN1(LL)=TX(7)
0118    95    CONTINUE
0119          TAU(INDEX) = TX(7)
0120          TRAN1(LMAX+1) = IV
0121          IL = (LMAX+1)*2
0122          IF(IRAD.NE.0) CALL WRITF(IDCB,IERR,TRAN1,IL)
0123          IF(IERR.EQ.-1) GO TO 110
0124          IF(IV.GE.IV2) GO TO 96
0125          GO TO 50
0126    96    WRITE(6,496)
0127          DO 97 LL=1,LMAX
0128          FAC = WW(LL,3)
0129          WH2O(LL) = WW(LL,5)/FAC
0130          WO3(LL) = WW(LL,6)/FAC
0131          WGAS(LL) = FAC
0132    C
0133    C***** TEMPORARY PRINT OUT
0134    C
0135    97    WRITE(6,498) LL,LYR(LL),ALT(LL),TEMP(LL),PRES(LL),WH2O(LL)
0136         1,WO3(LL),WGAS(LL)
0137          IPRM = 1
0138          NAME(3) = 2H6
0139          IF(IRAD.EQ.0) GO TO 102
0140          IF(WRITF(IDCB,IERR,IBUF,-1)) 110,101,101
0141    101   IF(CLOSE(IDCB,IERR)) 110,102,102
0142    102   CALL EXEC(8,NAME)
0143          CALL MRDA
0144    110   WRITE(6,500) IERR
0145          STOP
0146    422   FORMAT (/////"  FREQ WAVELENGTH  TOTAL   "
0147         1" N2 CONT  H2O CONT MOL SCAT AEROSOL AEROSOL INTEGRATED"
0148         2/1X,14H CM-1  MICRONS,4(4X5HTRANS),4X,"TRANS    ABS   ABSORP"
0149         3"TION"/)
0150    423   FORMAT (I6,7F9.4,F10.2)
0151    496   FORMAT(///1X,"LL",3X,"LEVEL",2X,"ALTITUDE",3X,"TEMP",6X,"PRES",
0152         17X,"WH2O",7X,"WO3",8X,"WGAS"/)
0153    498   FORMAT(I3,I6,3F10.2,2X,3E11.3)
0154    500   FORMAT(/"DISK I/O ERROR, IERR =",I3)
0155          END

**  NO ERRORS**     PROGRAM = 01602       COMMON = 05533
```

```
0001          FTN,L
0002          PROGRAM SECT6 (5,90)
0003          DIMENSION IDCB(144),JDCB(144),ISIZE(2),NAM1(3),NAM2(3)
0004          DIMENSION NUM(6),KPTS(3,40),CON(6),SPEC(6,2),Z(2)
0005          DIMENSION NAME(3),PP(9),TT(9),TRAN1(41),TRAN2(41)
0006          DIMENSION BUF(63)
0007          COMMON TEMP(40),PRES(40),V1,V2,DV,IRAD,LMAX,TAU(21)
0008          COMMON WH2O(40),WO3(40),WGAS(40),VV(250),AK(9,250)
0009          INTEGER SPEC
0010          DATA CON /0.0,.330E-3,0.0,75E-7,1.6E-6/
0011          DATA NAME /2HSE,2HGT,2H7 /,NAM1/2HTR,2HAN,2H1 /
0012          DATA NAM2 /2HTR,2HAN,2H2 /
0013    C
0014    C***** READ CONTINUUM TAU'S FOR RADIATION CALC
0015    C
0016          IOPTN = 0
0017          IF(IRAD.EQ.0) GO TO 70
0018          IF(OPEN(IDCB,IERR,NAM1,IOPTN)) 500,60,60
0019    60    IF(READF(IDCB,IERR,TRAN1)) 500,61,61
0020    61    IF(READF(IDCB,IERR,TRAN2)) 500,62,62
0021    62    RV1 = TRAN1(LMAX+1)
0022          RV2 = TRAN2(LMAX+1)
0023    70    CONTINUE
0024          IB = 1
0025          ISIZE(1) = 50
0026          IF(CREAT(JDCB,IERR,NAM2,ISIZE,3)) 500,95,95
0027    C
0028    C***** INSURE THAT (V1,V2) ARE WITHIN TAPES RANGE
0029    C
0030    95    READ(5,900) DVM
0031          IF(DVM.LT.0.005) DVM=0.005
0032          WRITE(6,938) DVM
0033          MSPEC = 6
0034    C
0035    C***** READ TAPE BLOCK INTO DISK FILE
0036    C
0037          REWIND 8
0038          READ(8,900) VMIN,VMAX,NPT
0039          IF(V2.GT.VMIN) GO TO 105
0040    100   WRITE(6,942) V1,V2,VMIN,VMAX
0041          STOP
0042    105   IF(V1.GE.VMAX) GO TO 100
0043    120   IF(V1.GE.VMIN) GO TO 122
0044          WRITE(6,930) V1,VMIN
0045          V1 = VMIN
0046    122   IF(V2.LE.VMAX) GO TO 123
0047          WRITE(6,931) V2,VMAX
0048          V2 = VMAX
0049    123   CONTINUE
0050    C
0051    C***** READ P,T VALUES FROM DISK FILE
0052    C
0053          READ(8,901)(PP(K),K=1,NPT)
0054          READ(8,901)(TT(K),K=1,NPT)
0055    C
0056    C***** DETERMINE INTERPOLATION POINTS FOR EACH LAYER
```

```
0057  C
0058        CALL PTPTS(PP,TT,LMAX,KPTS)
0059  C
0060  C***** READ IN WAVENUMBER BLOCKS
0061  C
0062        VCHK1 = V1-10.
0063        VCHK2 = V2+10.
0064        ILP = 1
0065  125   NUM1 = 1
0066        READ(8,900) VA,VB
0067        DO 128 M=1,MSPEC
0068        READ(8,902) SPEC(M,1),SPEC(M,2),NUM2
0069        NUM(M) = NUM1
0070        NUM1 = NUM1+NUM2
0071        NMIN = NUM(M)
0072        NMAX = NUM1-1
0073        IF(NMAX.GT.250) WRITE(6,933) VA,NMAX,M
0074        DO 127 N=NMIN,NMAX
0075  127   READ(8,903) VV(N),(AK(K,N),K=1,NPT)
0076  128   CONTINUE
0077        IF(VA.GT.VCHK1) GO TO 129
0078        WRITE(6,933) VA,(NUM(N),N=1,6),NMAX
0079        GO TO 125
0080  129   IF(VA.GE.VCHK2) GO TO 160
0081  C
0082  C***** CALCULATE TRANSMISSION
0083  C
0084        WRITE(6,906) NUM(1),NUM(6)
0085        IF(ILP.EQ.1) WRITE(6,932)
0086        ILP = ILP+1
0087        V = VV(NMIN)
0088        V0 = V
0089        N = 0
0090  135   IF(V.GE.V1) GO TO 136
0091        N = N+1
0092        V = V0 + FLOAT(N)*DVM
0093        GO TO 135
0094  136   N = 0
0095        V0 = V
0096  140   N = N+1
0097        RAD = 0.0
0098        RAD1 = 1.0
0099        FAC1 = 0.0
0100  C***** CONTINUUM TAU'S FOR RADIANCE CALC
0101        IF(IRAD.EQ.0) GO TO 1404
0102  1401  IF(RV2.GE.V) GO TO 1404
0103        DO 1402 LL=1,LMAX
0104  1402  TRAN1(LL) = TRAN2(LL)
0105        RV1 = RV2
0106        IF(READF(IDCB,IERR,TRAN2)) 500,1403,1403
0107  1403  RV2 = TRAN2(LMAX+1)
0108        GO TO 1401
0109  1404  CONTINUE
0110        DO 150 LL=1,LMAX
0111        DIST = WGAS(LL)
0112        CON(1) = WH2O(LL)
```

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0113          CON(3) = W03(LL)
0114          FAC2 = 0.0
0115          PBAR = PRES(LL)
0116          IF(PBAR.LT.75.) PBAR=75.
0117          DO 142 M=1,MSPEC
0118          IF(AK(1,NUM(M)).EQ.0.0) GO TO 142
0119          M1 = NUM(M)
0120  1405    VV1 = VV(M1)
0121          VV2 = VV(M1+1)
0122          IF(V.LE.VV2) GO TO 1406
0123          M1 = M1 + 1
0124          GO TO 1405
0125  1406    CONTINUE
0126  141     DO 1411 I=1,2
0127          N1 = M1+I-1
0128          Y0 = AK(KPTS(2,LL),N1)
0129          FT = F1(Y0,AK(KPTS(1,LL),N1),TT(KPTS(2,LL)),TT(KPTS(1,LL))
0130         1,TEMP(LL))
0131          FP = F1(Y0,AK(KPTS(3,LL),N1),PP(KPTS(2,LL)),PP(KPTS(3,LL))
0132         1,PBAR)
0133          AKK = FT+FP-Y0
0134          IF(AKK.LT.0) AKK=0
0135          IF(PBAR.LT.75.1)AKK=AKK*TEMP(LL)/216.6
0136          IF(VV(N1).EQ.V) GO TO 1412
0137          Z(I) = AKK
0138  1411    CONTINUE
0139          AKK = F1(Z(1),Z(2),VV1,VV2,V)
0140  1412    FAC2 = FAC2 + AKK*CON(M)*DIST
0141  142     CONTINUE
0142          FAC2 = FAC2*1.0E5
0143          IF(IRAD.EQ.0) GO TO 149
0144          TRN = 0.0
0145          IF(FAC2.LT.20.) TRN = EXP(-FAC2)
0146          PLANK = BLAM(TEMP(J),V)
0147          RAD = TRN*RAD+(1.0-TRN)*PLANK
0148          FAC4 = F1(TRAN1(LL),TRAN2(LL),RV1,RV2,V)
0149          FAC5 = 1.0
0150          IF(LL.NE.LMAX) FAC5 = F1(TRAN1(LL+1),TRAN2(LL+1),RV1,RV2,V)
0151          RAD1 = RAD1 + (FAC5-FAC4)*PLANK
0152  149     FAC1 = FAC1+FAC2
0153  150     CONTINUE
0154          RAD = RAD+RAD1
0155          TRAN = 0.0
0156          IF(FAC1.LT.20.) TRAN = EXP(-FAC1)
0157          BUF(IB) = V
0158          BUF(IB+1) = TRAN
0159          BUF(IB+2) = RAD
0160          IB = IB+3
0161          IL = (IB-1)*2
0162          IF(IB.NE.64) GO TO 155
0163          IB = 1
0164          IF(WRITF(JDCB,IERR,BUF,IL)) 500,155,155
0165  155     WRITE(6,934) V,TRAN,RAD
0166          V = V0 + FLOAT(N)*DVM
0167          IF(V.GT.V2) GO TO 160
0168          IF(V.LE.VB) GO TO 140
```

```
0169          N = N-1
0170          GO TO 125
0171   160    IF(WRITF(JDCB,IERR,BUF,IL)) 500,165,165
0172   165    IF(WRITF(JDCB,IERR,BUF,-1)) 500,170,170
0173   170    IF(IRAD.EQ.1) IF(PURGE(IDCB,IERR,NAM2)) 500,175,175
0174   175    IF(CLOSE(JDCB,IERR)) 500,180,180
0175   180    CALL EXEC(8,NAME)
0176          CALL MRDA
0177   500    WRITE(6,940) IERR
0178          STOP
0179   900    FORMAT(2F10.2,I5)
0180   901    FORMAT(9F10.2)
0181   902    FORMAT(2A2,I5)
0182   903    FORMAT(F12.2,9E12.6)
0183   906    FORMAT("NMIN,NMAX=",2I10)
0184   930    FORMAT(//"V1 =",F10.2,5X,"TOO SMALL, RESET TO",F10.2," CM-1")
0185   931    FORMAT(//"V2 =",F10.2,5X,"TOO LARGE, RESET TO",F10.2," CM-1")
0186   932    FORMAT(//"     FREQ        TRAN      RAD",/)
0187   933    FORMAT("BLOCK SKIPPED, V =",F5.1," WAVENUMBERS",7I6)
0188   934    FORMAT(F10.2,F10.4,2E10.3)
0189   936    FORMAT(2I10)
0190   938    FORMAT(/"MEDIUM RESOLUTION DV =",F5.1," WAVENUMBERS"/)
0191   940    FORMAT(//"DISK I/O ERROR, IERR =",I3)
0192   942    FORMAT("TAPE OUT OF RANGE OF DATA"/"V1 =",F7.1,", V2 ="
0193         1,F7.1,", VMIN =",F7.1,", VMAX =",F7.1)
0194          END

**  NO ERRORS**     PROGRAM = 02397       COMMON = 05450
```

```
        PAGE  0001          FTN4 COMPILER: HP24177  (SEPT. 1974)

0199          FUNCTION BLAM(T,V)
0200          BLAM = 1.1989E-16*V**5/EXP(1.4338*V/T-1.)
0201          RETURN
0202          END

**  NO ERRORS**     PROGRAM = 00050       COMMON = 00000
```

```
        PAGE  0001          FTN4 COMPILER: HP24177  (SEPT. 1974)

0195          FUNCTION F1(Y1,Y2,X1,X2,X)
0196          F1 = Y1+(Y2-Y1)*(X-X1)/(X2-X1)
0197          RETURN
0198          END
```

```
0001          FTN,L
0002          PROGRAM SEGT7 (5,90)
0003          COMMON TEMP(40),PRES(40),V1,V2,DV,IRAD,LMAX,TAU(21)
0004          COMMON WH2O(40),WO3(40),WGAS(40),VV(250),AK(9,250)
0005          DIMENSION V(1001),NAM2(3)
0006          DIMENSION JDCB(144),BUF(63),TR(2,1050)
0007          EQUIVALENCE (WH2O,TR(1,1))
0008          DATA NAM2/2HTR,2HAN,2H2 /
0009          IK = 1
0010          NUMV = 0
0011          IOPTN = 0
0012          IF(OPEN(JDCB,IERR,NAM2,IOPTN)) 100,10,10
0013    10    IF(READF(JDCB,IERR,BUF,128,LEN)) 100,11,11
0014    11    IF(LEN.EQ.-1) GO TO 20
0015          LEN = LEN/6
0016          NUMV = NUMV+LEN
0017          DO 15 I=1,LEN
0018          V(IK) = BUF(I*3-2)
0019          TR(1,IK) = BUF(I*3-1)
0020          TR(2,IK) = BUF(I*3)
0021          IK = IK+1
0022    15    CONTINUE
0023          GO TO 10
0024    C
0025    C***** FOLD IN CONTINUUM RESULTS
0026    C
0027    20    IF(RWNDF(JDCB,IERR)) 100,21,21
0028    21    IMAX = I-1
0029          DO 25 I=1,NUMV
0030          CALL CALC2(V(I),T)
0031    25    TR(1,I) = T*TR(1,I)
0032          IF(IRAD.EQ.0) TR(2,I) = 0.0
0033          WRITE(6,902)
0034          II=0
0035          DO 70 I=1,NUMV
0036          II=II+1
0037          WRITE(6,903) V(I),TR(1,I),TR(2,I)
0038          BUF(II*3-2) = V(I)
0039          BUF(II*3-1) = TR(1,I)
0040          BUF(II*3) = TR(2,I)
0041          IF(II.NE.21) GO TO 70
0042          IL = 126
0043          IF(WRITF(JDCB,IERR,BUF,IL)) 100,55,55
0044    55    II=0
0045    70    CONTINUE
0046          IL = II*6
0047          IF(WRITF(JDCB,IERR,BUF,IL)) 100,80,80
0048    80    STOP
0049    100   WRITE(6,904) IERR
0050          GO TO 80
0051    902   FORMAT(//"   V        TRANS    RAD"/)
0052    903   FORMAT(F6.1,2F8.4)
0053    904   FORMAT(//"DISK I/O ERROR, IERR =",I3)
0054          END
```

```
0001          FTN,L
0002          SUBROUTINE POINT (X,YN,N,NP,TX,IP)
0003          COMMON TEMP(40),PRES(40),V1,V2,DV,IPAD,LMAX,AHZ2(20)
0004          COMMON RANGE,WW(40,8)
0005          COMMON Z(34),P(34),T(34),EH(8,34),WH(34),M,NL,RE,CW,CO,PI
0006          DIMENSION TX(10)
0007    C*****************************************************************
0008    C     SUBROUTINE POINT COMPUTES THE MEAN REFRATIVE INDEX ABOVE AND BELOW
0009    C     A GIVEN ALTITUDE AND INTERPOLATES EXPONENTIALLY TO DETERMINE THE
0010    C     EQUIVALENT ABSORBER AMOUNTS AT THAT ALTITUDE.
0011    C
0012    C*****************************************************************
0013    C
0014    C       X IS THE HEIGHT IN QUESTION
0015    C       TX(7) AND YN ARE THE MEAN REFRACTIVE INDICES ABOVE AND BELOW X
0016    C       N IS THE LEVEL INTEGER CORRESPONDING TO X OR THE LEVEL BELOW X
0017    C       NP =1 IF X COINCIDES WITH MODEL ATMOSPHERE LEVEL ,IF NOT NP = 0
0018    C       TX(1-6) ARE ABSORBER  AMOUNTS PER KM AT HEIGHT X
0019    C*****************************************************************
0020          N=NL
0021          NP=0
0022          IF (X.LT.0.0) X=0.
0023          IF (X.GT.Z(NL)) GO TO 4
0024          DO 1 I=1,NL
0025          N=I
0026          IF (X-Z(I)) 2,4,1
0027    1     CONTINUE
0028    2     J2=N
0029          N=N-1
0030          FAC=(X-Z(N))/(Z(J2)-Z(N))
0031          PX1=P(N)*(P(J2)/P(N))**FAC
0032          TX1=T(N)*(T(J2)/T(N))**FAC
0033          TX(9) = TX1
0034          TX(10)= PX1
0035          WX1=WH(N)*(WH(J2)/WH(N))**FAC
0036          TX(3) = CO*PX1/TX1-4.56E-6*WX1*TX1*CW
0037          TX(2) = CO*P(J2)/T(J2)-4.56E-6*WH(J2)*T(J2)*CW
0038          TX(1) = CO*P(N)/T(N)-4.56E-6*WH(N)*T(N)*CW
0039          TX(7) = 0.5E-6*(TX(2)+TX(3))
0040          YN = 0.5E-6*(TX(1)+TX(3))
0041          IF (IP.EQ.0) GO TO 9
0042          DO 3 L=1,7
0043          k=L
0044          IF(L.EQ.7) K=8
0045          IF (EH(K,N).EQ.0.0) GO TO 3
0046          IF (EH(K,N).GT.1000.0) GO TO 3
0047          TX(K)=EH(K,N)*(EH(K,J2)/EH(K,N))**FAC
0048    3     CONTINUE
0049          GO TO 9
0050    4     NP=1
0051          IF (IP.EQ.0) GO TO 6
0052          DO 5 K=1,8
0053    5     TX(K)=EH(K,N)
0054    6     TX(7)=EH(7,N)-1.
0055          YN=0.0
0056          IF (N.GT.1) YN=EH(7,N-1)-1.0
```

```
0057  9      CONTINUE
0058         IF (IP.EQ.1)WRITE(6,400) X,N,NP,TX(7),YN,IP,(TX(K),K=1,4)
0059         TX(7)=TX(7)+1.
0060         YN=YN+1.
0061         RETURN
0062  C
0063  400    FORMAT (/," FROM POINT, HEIGHT=",F10.4," KM,N=",I3,",NP=",I2,",REF
0064        1. INDEX ABOVE & BELOW X=",2E11.4,",IP=",I3,/,12X,"EQUIV. ABSORBER
0065        2AMOUNTS PER KM AT X=",4E10.3)
0066         END

**  NO ERRORS**     PROGRAM = 00766       COMMON = 01676
```

```
0001          FTN,L
0002          SUBROUTINE PTPTS(PP,TT,IMAX,KPTS)
0003          DIMENSION PP(9),TT(9),KPTS(3,40)
0004          COMMON TEMP(40),PRES(40)
0005    C
0006    C***** PROGRAM WRITTEN FOR 9 P,T POINTS
0007    C
0008          DO 60 J=1,IMAX
0009          P0 = PRES(J)
0010          T0 = TEMP(J)
0011    C     IF(ICALC2.GT.0) GO TO 50
0012    C     ICALC2 = 1
0013    C
0014    C***** FIRST CALL AT GIVEN P,T---LOCATE INTERPOLATION POINTS
0015    C
0016          IF(P0.GT.PP(5).AND.T0.GT.TT(5)) GO TO 15
0017          IF(P0.GT.PP(3)) GO TO 5
0018          K1 = 1
0019          K2 = 2
0020          K3 = 3
0021          IF(T0.LE.TT(2)) GO TO 50
0022          K1 = 4
0023          K2 = 3
0024          K3 = 2
0025          GO TO 50
0026    5     IF(P0.GT.PP(5)) GO TO 10
0027          K1 = 3
0028          K2 = 4
0029          K3 = 5
0030          IF(T0.LE.TT(5)) GO TO 50
0031          K1 = 6
0032          K2 = 5
0033          K3 = 4
0034          GO TO 50
0035    10    K1 = 6
0036          K2 = 5
0037          K3 = 7
0038          PMID = .5*(PP(5)+PP(7))
0039          IF(P0.LT.PMID) GO TO 50
0040          K1 = 8
0041          K2 = 7
0042          K3 = 5
0043          GO TO 50
0044    15    IF(P0.GT.PP(7)) GO TO 25
0045          K1 = 9
0046          K2 = 8
0047          K3 = 6
0048          IF(T0.GT.TT(6)) GO TO 50
0049          A6 = (T0-TT(6))**2+(P0-PP(6))**2
0050          A7 = (T0-TT(7))**2+(P0-PP(7))**2
0051          IF(A6.GT.A7) GO TO 20
0052          K1 = 5
0053          K2 = 6
0054          K3 = 8
0055          GO TO 50
0056    20    IF(T0.GE.TT(8)) GO TO 30
```

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```
0057            K1 = 8
0058            K2 = 7
0059            K3 = 5
0060            GO TO 50
0061   25       TMID = .5*(TT(7)+TT(8))
0062            K1 = 8
0063            K2 = 7
0064            K3 = 5
0065            IF(T0.LE.TMID) GO TO 50
0066            K1 = 7
0067            K2 = 8
0068            K3 = 6
0069            GO TO 50
0070   30       K1 = 9
0071            K2 = 8
0072            K3 = 6
0073   50       CONTINUE
0074            KPTS(1,J) = K1
0075            KPTS(2,J) = K2
0076            KPTS(3,J) = K3
0077   60       CONTINUE
0078            RETURN
0079            END
```

** NO ERRORS** PROGRAM = 00426 COMMON = 00160

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```
        PAGE  0001          FTN4 COMPILER: HP24177  (SEPT. 1974)


0001            FTN,L
0002            SUBROUTINE CALC2(V,T2)
0003            COMMON TEMP(40),PRES(40),V1,V2,DV,IRAD,LMAX,TAU(21)
0004            VI = V1
0005            VF = V1+DV
0006            DO 10 I=1,19
0007            IF(V.GE.V1.AND.V.LT.VF) GO TO 20
0008            VI = VI + DV
0009   10       VF = VF + DV
0010   20       T2 = TAU(I) + ((TAU(I+1)-TAU(I))/DV)*(V-VI)
0011            RETURN
0012            END
```

```
        PAGE  0001          FTN4 COMPILER: HP24177  (SEPT. 1974)


0001            FTN,L
0002            FUNCTION ASIN(A)
0003            TEST = 1.0 - ABS(A)
0004            ARG = A/SQRT(1.-A**2)
0005            ASIN = ATAN(ARG)
0006            IF(TEST.LT.1.E-8) ASIN = 2.0*ATAN(1.0)
0007            RETURN
0008            END
```

```
        PAGE  0001          FTN4 COMPILER: HP24177  (SEPT. 1974)

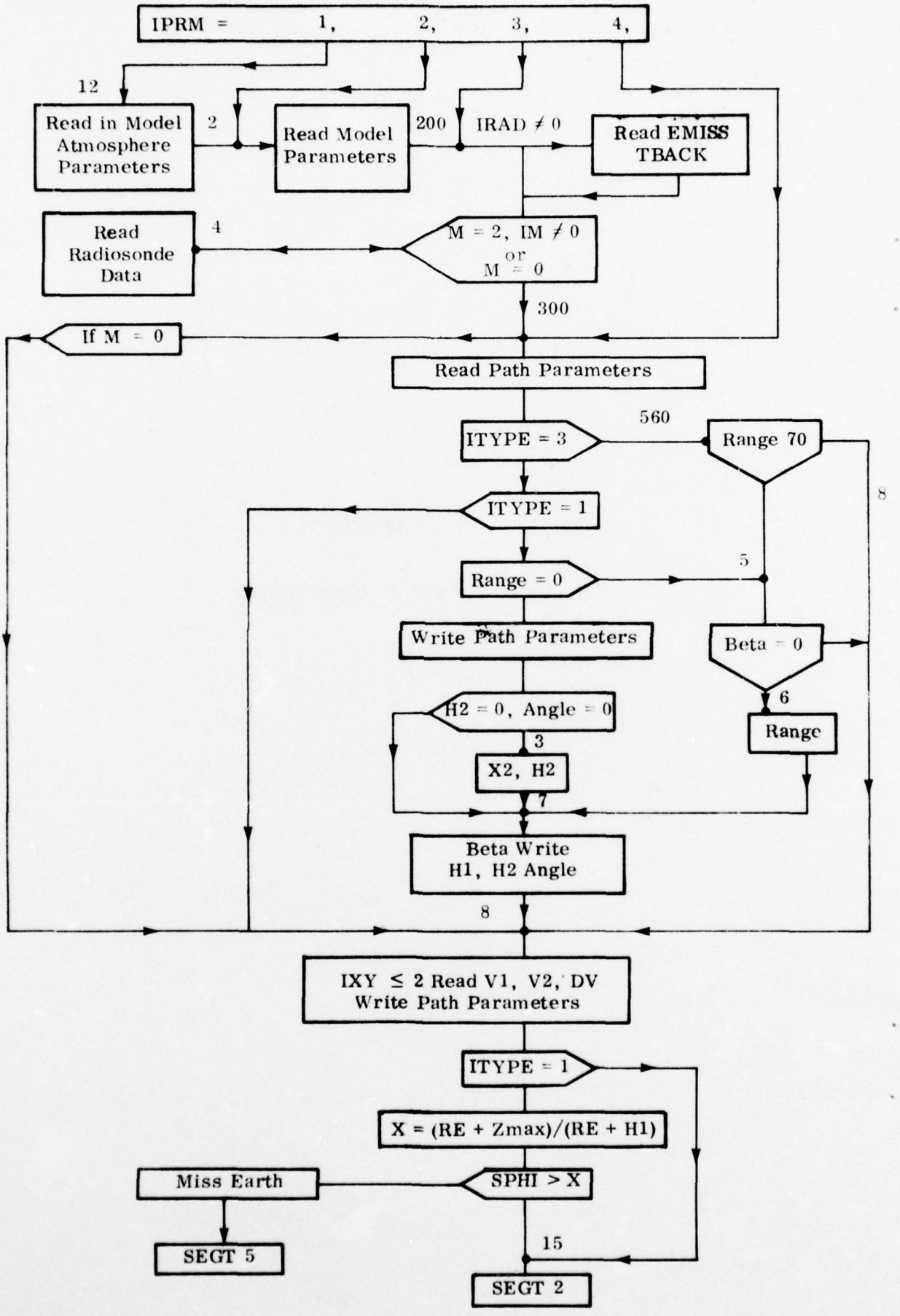

0001            FTN,L
0002            FUNCTION ACOS(A)
0003            ARG = SQRT(1.-A**2)/A
0004            ACOS = ATAN(ARG)
0005            IF(A.LT.1.E-8) ACOS = 2.0*ATAN(1.0)
0006            RETURN
0007            END
```

```
        PAGE  0001          FTN4 COMPILER: HP24177  (SEPT. 1974)

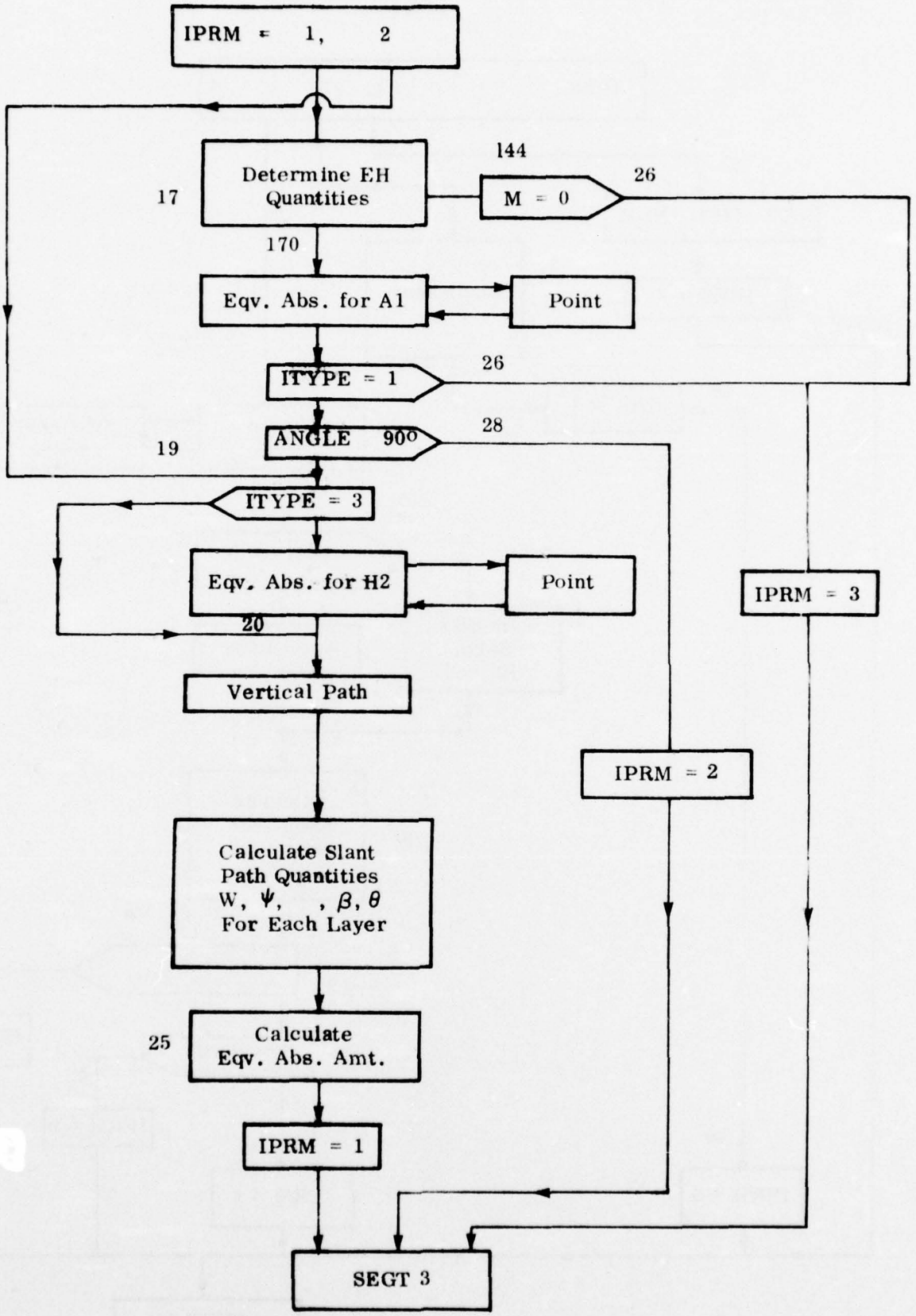

0001            FTN,L
0002            FUNCTION F(A)
0003            F = EXP(18.9766-14.9595*A-2.43882*A*A)*A
0004            RETURN
0005            END
```

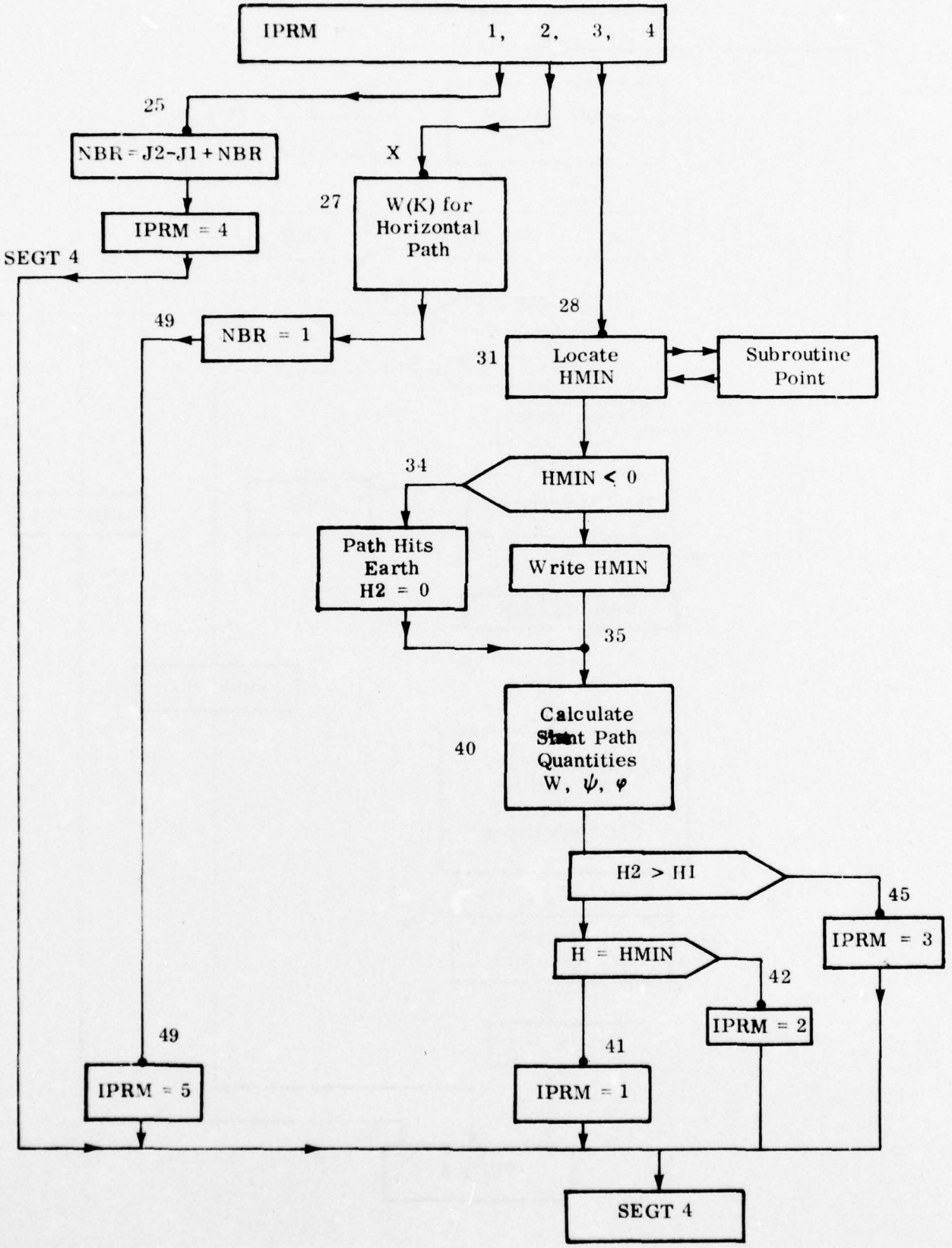
APPENDIX B

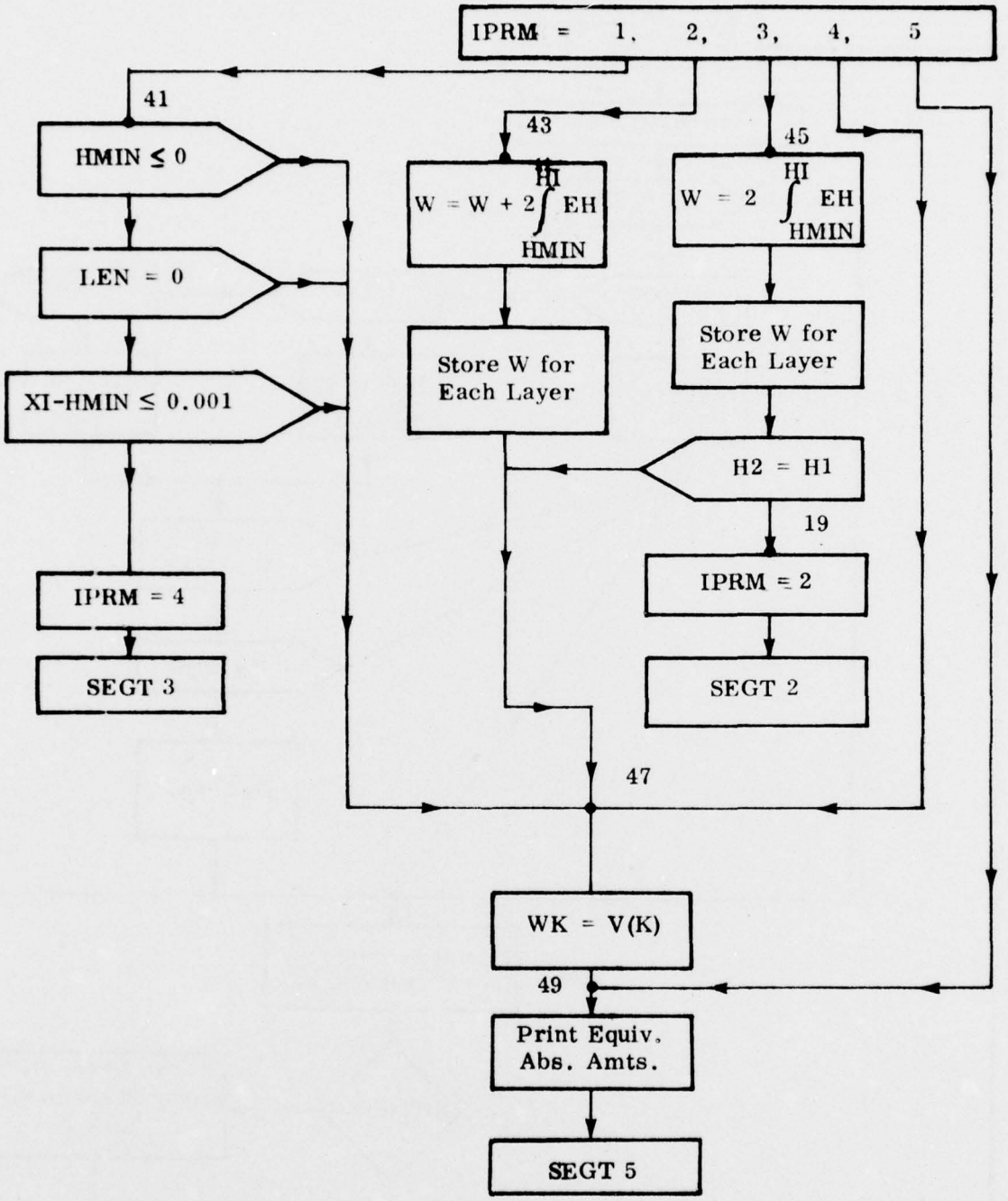
MRDA FLOW CHART

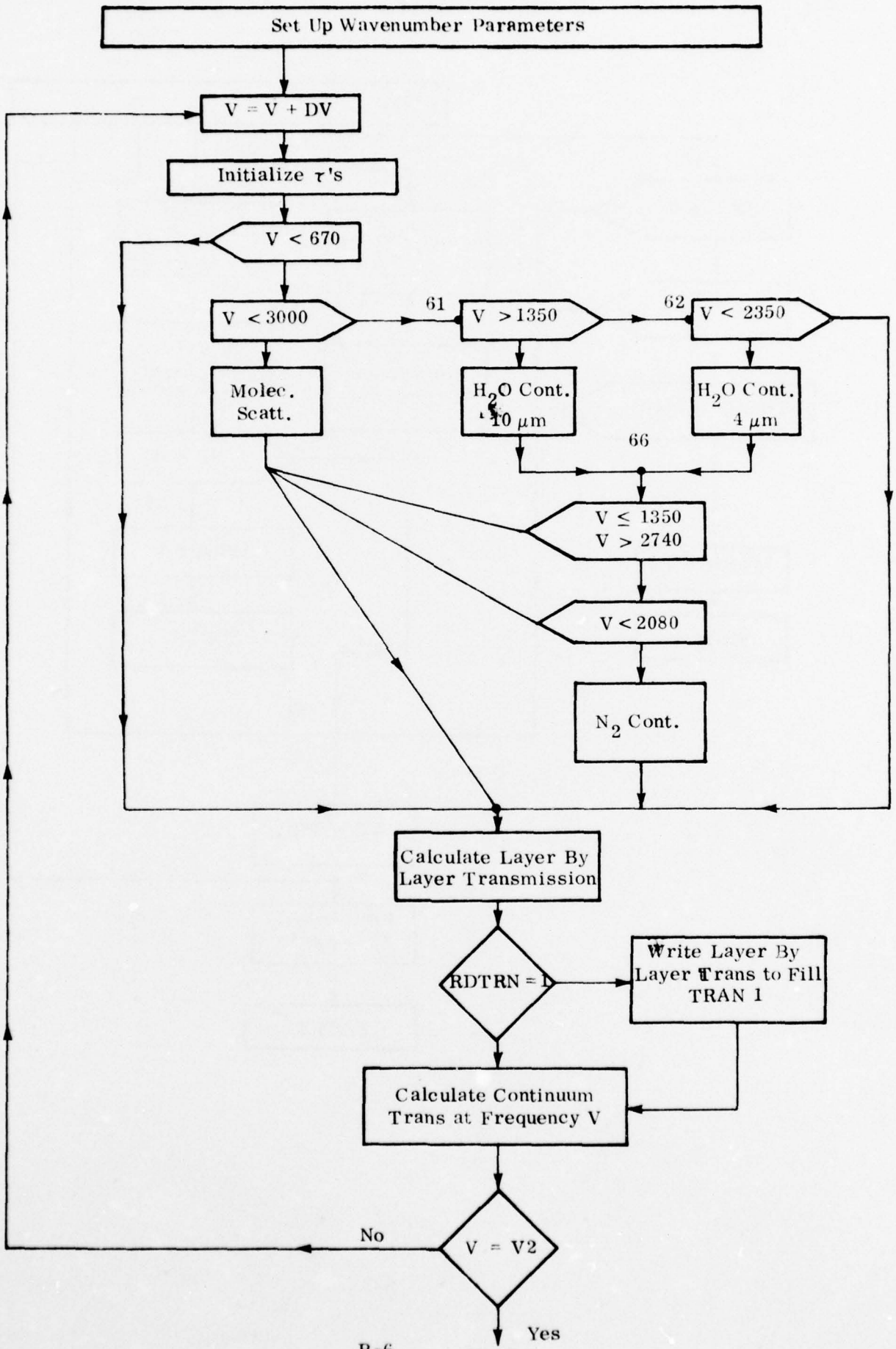

IPRM = 1, 2, 3, 4,
12
Read in Model Atmosphere Parameters
2
Read Model Parameters
200
IRAD ≠ 0
Read EMISS TBACK
Read Radiosonde Data
4
M = 2, IM ≠ 0 or M = 0
300
If M = 0
Read Path Parameters
560
ITYPE = 3
Range 70
8
ITYPE = 1
5
Range = 0
Write Path Parameters
Beta = 0
6
Range
H2 = 0, Angle = 0
3
X2, H2
7
Beta Write H1, H2 Angle
8
IXY ≤ 2 Read V1, V2, DV Write Path Parameters
ITYPE = 1
X = (RE + Zmax)/(RE + H1)
Miss Earth
SPHI > X
SEGT 5
15
SEGT 2

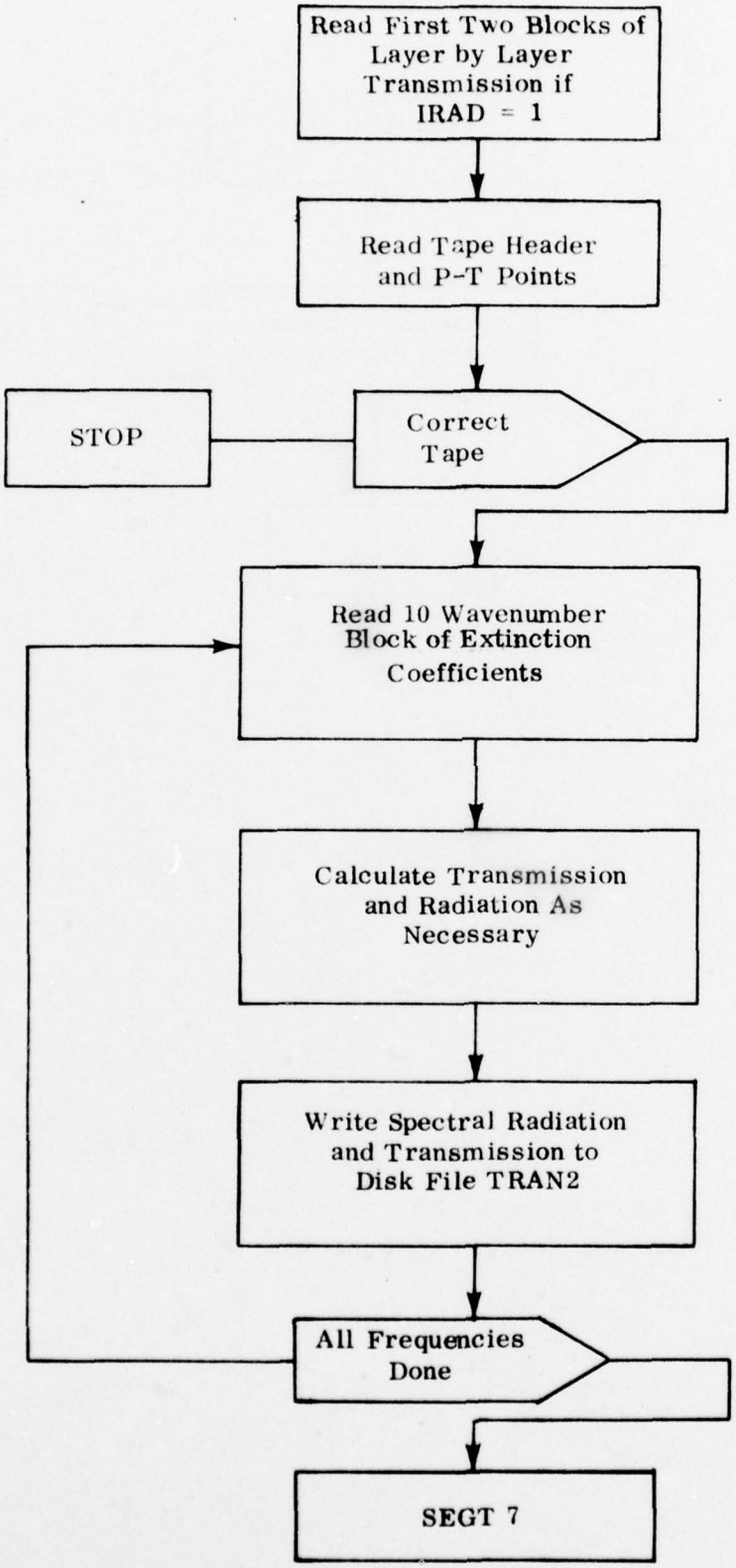
SEGT 2

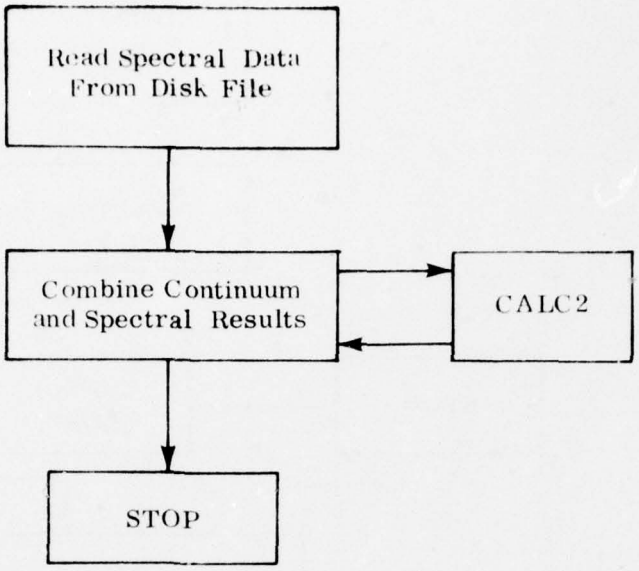

IPRM = 1, 2
144
17
Determine EH Quantities
M = 0
26
170
Eqv. Abs. for A1
Point
ITYPE = 1
26
ANGLE 90°
28
19
ITYPE = 3
Eqv. Abs. for H2
Point
IPRM = 3
20
Vertical Path
IPRM = 2
Calculate Slant Path Quantities W, ψ, , β, θ For Each Layer
25
Calculate Eqv. Abs. Amt.
IPRM = 1
SEGT 3


IPRM 1, 2, 3, 4
25
NBR = J2-J1 + NBR
IPRM = 4
SEGT 4
X
27
W(K) for Horizontal Path
49
NBR = 1
28
31
Locate HMIN
Subroutine Point
34
HMIN < 0
Path Hits Earth H2 = 0
Write HMIN
35
40
Calculate Point Path Quantities W, ψ, φ
H2 > H1
45
IPRM = 3
H = HMIN
42
IPRM = 2
41
IPRM = 1
49
IPRM = 5
SEGT 4


IPRM = 1, 2, 3, 4, 5
41
HMIN ≤ 0
LEN = 0
XI-HMIN ≤ 0.001
IPRM = 4
SEGT 3
43
W = W + 2 ∫ EH (HI, HMIN)
Store W for Each Layer
45
W = 2 ∫ EH (HI, HMIN)
Store W for Each Layer
H2 = H1
19
IPRM = 2
SEGT 2
47
WK = V(K)
49
Print Equiv. Abs. Amts.
SEGT 5


Set Up Wavenumber Parameters
V = V + DV
Initialize τ's
V < 670
V < 3000
61
V > 1350
62
V < 2350
Molec. Scatt.
H2O Cont. 10 μm
H2O Cont. 4 μm
66
V ≤ 1350
V > 2740
V < 2080
N2 Cont.
Calculate Layer By Layer Transmission
RDTRN = 1
Write Layer By Layer Trans to Fill TRAN 1
Calculate Continuum Trans at Frequency V
V = V2
No
Yes
SEGT 6


Read First Two Blocks of Layer by Layer Transmission if IRAD = 1
Read Tape Header and P-T Points
STOP
Correct Tape
Read 10 Wavenumber Block of Extinction Coefficients
Calculate Transmission and Radiation As Necessary
Write Spectral Radiation and Transmission to Disk File TRAN2
All Frequencies Done
SEGT 7


Read Spectral Data
From Disk File
Combine Continuum
and Spectral Results
CALC2
STOP

APPENDIX C

LIST OF SYMBOLS

SEGMENT 1

ALAM	Wavelength (μm)
ANGLE	Input zenith angle (degrees) (compare with θ_o in the text)
AVW	Average wavelength used in refractive index expression
BET	Angle subtended at the earth's center as path traverses adjacent levels (cf β_i in Eq. (8))
BETA	Total angle subtended by path at earth's center (compare β in Eq. (9)
CA	Conversion factor from degrees to radians
CO	Wavelength dependent coefficient used in refractive index expression
CW	Wavelength dependent coefficient used in refractive index expression
C7	Extinction coefficient for aerosol models
C7A	Aerosol absorption coefficient
DP	Dew point temperature (^{o}C)
DV	Wavenumber increment at which transmittance is calculated
HMIN	Minimum altitude of path trajectory (km)
H1	Initial altitude (km)
H2	Final altitude (km)
HZ1	Aerosol number density (no. cm^{-3}) for 23 km visual range
HZ2	Aerosol number density (no. cm^{-3}) for 5 km visual range
I	Running integer used as altitude (level) indicator and frequency indicator
IHAZE	Aerosol model indicator
IM	Parameter used when reading in a new atmospheric model (see Section 5.2.1)
IP	Indicator for using subroutine POINT to calculate refractive index only (IP = 0) or equivalent absorber amounts also (IP $\neq$ 0).
IPRM	Flag for segment communication
ITYPE	Indicator for type of atmospheric path (see Section 5.1)
IXY	Parameter for terminating program and cycling indicator
J	Running integer for altitude identification
JP	Print option parameter
J1	Level indicator for altitude H1
J2	Level indicator for altitude H2
L	Index for levels

LEN	Parameter used for defining longer of two paths (see Section 5.1)
M	Integer used to identify required model atmosphere
ML	Number of levels in radiosonde data input (MODEL = 2)
MODEL	Integer used to identify required model atmosphere (see Section 5.1)
NAME	ASCII Name of next segment to be called
NL	Number of levels in model atmosphere
NLDAT	Number of layers in model atmosphere data
P(I)	Pressure (mb) at level I
PI	3.141592654 that is (π)
RANGE	Path length (km)
RE	Earth radius (km)
RH	Relative humidity (%)
RI	The product of the sine of the initial zenith angle and the earth center distance to starting altitude
SPHI	Sine of the local zenith angle at a given level (cf sin θ)
SR	Slant range (km)
T(I)	Temperature (^{O}K) at level I
TBACK	Background radiation calculation temperature
TMP	Ambient temperature (^{O}C)
TT	Ratio 273.15/(TMP + 273.15)
VH(K)	Integral of the equivalent absorber amounts from H1 to level I
VIS	Visual range (km) at sea level
VX	Wavelength at which aerosol coefficients are read in (μm)
V1	Initial frequency for transmittance calculation, cm^{-1}
V2	Final frequency for transmittance calculation, cm^{-1}
WH(I)	Water vapor density at level I ($gm\ m^{-3}$)
WO(I)	Ozone density at level I ($gm\ m^{-3}$)
X	Input height to POINT subroutine
X1	Earth center distance of level I
X2	Earth center distance of level I + 1
Y	Input zenith angle in radians
Z(I)	Altitude at level I in km

SEGMENT 2

AHAZE	Aerosol number density for MODEL = 1
AHZ2	Aerosol number density for MODEL = 2
ALT(LL)	Altitude at level Z(LYR(LL))
ANGLE	Input zenith angle (degrees) (compare with θ_o in the text)
CO	Wavelength dependent coefficient used in refractive index expression
CW	Wavelength dependent coefficient used in refractive index expression
D	Water vapor amount (pr. cm/km) at level I
DS	Path length from level I to Level I + 1
DZ	Height increment from level I to level I + 1
EH	Equivalent absorber amounts
EV	Integrated absorber amount from level I to level I + 1
HAZE	Aerosol number density (no. cm^{-3})
H1	*Initial Altitude*
H2	Final Altitude
HZ1	Aerosol number density (no. cm^{-3}) for 23 km visual range
HZ2	Aerosol number density (no. cm^{-3}) for 5 km visual range
IHAZE	Aerosol model indicator
IP	Indicator for using subroutine POINT to calculate refractive index only (IP = 0) or equivalent absorber amounts also (IP $\neq$ 0).
IPRM	Flag for segment communication
ITYPE	Indicator for type of atmospheric path (see Section 5.1)
JP	Print option parameter
L	Frequency indicator for ozone transmittance calculation
LBR	Layer counting parameter for slant path trajectory
LL	Level index
LYR(LL)	Level number of Lth Layer in the atmospheric path
M	Integer used to identify model atmosphere

NAME	ASCII of next segment to be called
NL	Number of levels in model atmosphere data
NP1	Value of NP for altitude H1
PHI	Angle of arrival at H2
PS	Total pressure in atmospheres
PSI	Angular deviation of path from initial direction
PPW	Partial pressure H_2O
PRES(LL)	Pressure al level LL
PT	Product of total pressure (atm) and the square root of 273/T(M,I)
REF	Refractive index of air at level I
RN	Ratio of refractive indices of air above and below a given level
RX	Ratio of earth center distances between adjacent levels
SALP	Sine of angle of arrival at adjacent level
SPHI	Sine of the local zenith angle at a given level
SR	Slant range (km)
TEMP(LL)	Temperature at level LL
T(I)	Temperature (^{O}K) at level I
THETA	Zenith angle at a given level (in degrees)
TS	Ratio of standard temperature (273.0^{O}K) to temperature at level I
TX(K)	Equivalent absorber amounts per km at a giv en altitude obtained from POINT; also transmittance values at a given wavelength for each absorber type (K = 1, 8)
TX(9)	Total transmittance at frequency V
TX(10)	Absorption due to aerosol only at frequency V
TX1	Refractive index of layer above initial altitude H1
VIS	Visual range (km) at sea level
WH(I)	Water vapor density at level I (gm m^{-3})
WW	Equivalent absorber amount from observer to level L
W2	Water vapor density for atmospheric model M at level I + 1 (gm m^{-3})
X	Input height to POINT subroutine
X1	Earth center distance of level I
YN	Refractive index of layer below input height from POINT subroutine
Z(I)	Altitude at level I in km

SEGMENT 3

AL	Equivalent absorber amount per km at level L
ALT(LL)	Altitude of level LYR(LL)
AO	Constant A defined in Eq. (10) of LOWTRAN3 Manual
BET	Angle subtended at the earth's center as path traverses adjacent levels
BETA	Total angle subtended by path at earth's center
CA	Conversion factor from degrees to radians
DS	Path length from level I to Level I + 1
EV	Integrated absorber amount from level I to level I + 1
H	Altitude at which calculations are being made
HM	Estimated tangent height (km)
HMIN	Minimum altitude of path trajectory (km)
H1	Initial altitude
H2	Final altitude
I	Running integer used as altitude (level) indicator and frequency indicator
IP	Indicator for using subroutine POINT to calculate refractive index only (IP = 0) or equivalent absorber amounts also (IP $\neq$ 0).
IPRM	Flag for segment communication
JP	Print option parameter
K	Absorber indicator
K2	Cycling parameter for downward looking paths
L	Frequency indicator for transmittance calculation
LBR	Total Number of levels transversed in the path
LL	Level index
LMIN	Layer number of HMIN
LYR(LL)	Lth level in path
L1	Frequency identifier for transmittance calculation
L2	Frequency identifier for transmittance calculation

M	Integer used to identify required model atmosphere
NAME	Used to contain name of next segment called
NP1	Value of NP for altitude H1
NP2	Value of NP for altitude H2
P(I)	Pressure (mb) at level I
PRES(LL)	Pressure at level LL
PSI	Angular deviation of path from initial direction
Range	Path length (km)
RE	Earth radius (km)
REF	Refractive index of air at level I
RN	Ratio of refractive indices of air above and below a given level
RX	Ratio of earth center distances between adjacent levels
SALP	Sine of angle of arrival at adjacent level (cf $\sin\alpha$)
SPHI	Sine of the local zenith angle at a given level (cf $\sin\theta$)
SR	Slant range (km)
T(I)	Temperature (^{O}K) at level I
TEMP(LL)	Temperature at level LL
THET	Zenith angle at a given level (in radians)
THETA	Zenith angle at a given level (in degrees)
TMP	Ambient temperature (^{O}C)
TX(K)	Equivalent absorber amounts per km at a given altitude obtained from POINT; also transmittance values at a given wavelength for each absorber type (K = 1, 8)
TX(9)	Total transmittance at frequency V
TX(10)	Absorption due to aerosol only at frequency V
VH(K)	Integral of the equivalent absorber amounts from H1 to level I
W(K)	Total equivalent absorber amount for entire path
WW(K, L)	Equivalent absorber amount from observer to level LL
X	Input height to POINT subroutine
X2	Earth center distance of level I + 1
Y	Input zenith angle in radians
YN1	Refractive index of layer below initial altitude H1
YN2	Refractive index of layer below final altitude H2
Z(I)	Altitude at level I in km

SEGMENT 4

ALT(LL)	Altitude of layer L
B	Blackbody function
BETA	Total angle subtended by path at earth's center
CA	Conversion factor from degrees to radians
DV	Wavelength increment
E(K)	Equivalent absorber amounts per km at height H
H	Height
HM	Estimated height
HMIN	Minimum altitude of path tragectory
I	Frequency index
IPRM	Segment path indicator
IV1	Starting frequency
IV2	Last frequency
K2	Cycling parameter for downward path
L	Running index for layers
LBR	Layer counting parameters for slant path trajectories
LEN	Parameter used for defining longer of two paths
LL	Running index for levels
LLMIN	Value of LL at HMIN
LMAP	Counting variable for long path storage
LSTORE	Counting variable for layer index
LYR(LL)	Altitude of Lth layer in path
L2	Layer number of H2
NAME(3)	Used to identify next segment to be called
P(L)	Pressure at layer L
PH	Angle of arrival at H2
PMIN	Pressure at HMIN
PRES(LL)	Atmospheric pressure at layer L

PS	Total pressure in atmospheres
PSI	Angular deviation of path from initial direction
RN	Ratio of refractive indicies of Air above and below a given level
SPHI	Sine of local zenith angle at a given level
SR	Slant Range
T(L)	Temperature at layer L
TEMP(LL)	Temperature at layer LL
TMIN	Temperature at HMIN
TS	Ratio of standard temperature to temperature at level L
TX1	Refractive index of layer above initial altitude H1
VI	Initial frequency
VH(K)	Integral of the equivalent absorber amounts from H1 to level I
W(K)	Total equivalent absorber amount for entire path
WW(LL, K)	Equivalent absorber amounts from observer to level LL
X1	Earth center distance of level L
X2	Earth center distance of level L + 1
YN1	Refractive index of layer below initial altitude H1

SEGMENT 5

AB	Absorption at frequency V; also average transmittance
ALAM-	Wavelength (μm)
C4	Absorption coefficient for nitrogen (~4μm)
C5	Absorption coefficient for water vapor continuum
C6	Extenction coefficient for molecular scattering
C7	Extenction coefficient for aerosol models
C7A	Aerosol absorption coefficient
DV	Wavelength increment
IDV	Frequency increment
IHAZE	Aerosol model indicator
INDEX	Counting variable for frequency
IPRM	Segment path indicator
IRAD	Radiation calculation flag
IV	Frequency of calculations
IV1	Starting frequency
IV2	Last frequency
JP	Print option parameter
K4	Frequency indicator for nitrogen continuum transmission calculation
LL	Running index for level s
LMAX	Number of layers in the path
LOOP	Number of layers for low resolution radiance calculations
NAME	Used to idenfity next segment to be called
NH	Frequency indicator for water vapor continuum transmittance calculation
SUM	Sum of optical thicknesses of absorbers 4 through 8
SUMA	Accumulated integrated absorption
TAU(INDEX)	Transmittance
TRAN1(LL)	Transmittance of layer LL

TX(K)	Equivalent absorber amounts per km at a given altitude obtained from POINT; also transmittance values at a given wavelength for each absorber (K = 1, 4)
TX(5)	Total transmittance at frequency V
TX(6)	Absorption due to aerosol at frequency V
VH(K)	Integral of the equivalent absorber amounts from H1 to level I
VX	Wavelength of aerosol coefficients
W(K)	Total equivalent absorber amount for entire path
WGAS(LL)	Atmospheric gas density
WHZO(LL)	H_2O density
WO3(LL)	O_3 density
WW(LL, K)	Equivalent absorber amounts from observer to level LL
XD	Wavenumber interpolation parameter
XH	Wavenumber interpolation parameter in H_2O continuum calculation
XI	Wavenumber interpolation parameter
XX	Aerosol extinction coefficient
YY	Aerosol absorption coefficient of frequency V

SEGMENT 6

AK(K,N)	Extinction coefficient read from tape for Kth pressure-temperature point at frequency VV(N)
AKK	Interpolated extinction coefficient
BUF(63)	Disk write buffer containing frequency plus spectral transmission & radiance results
COMN(6)	Species concentrations
DIST	Optical depth of a species
DVM	MRDA frequency interval
FAC1	Log transmittance
FAC2	Summing variable for transmittance
FAC4	Log transmittance for radiation
FAC5	Log transmittance for radiation
FP	Intermediate result in interpolation of AK(K,N)
FT	Intermediate result in interpolation of AK(K,N)
ILP	Integer variable for printing heading
IRAD	Radiation calculation flag
KPTS(3,LL)	Elements in P-T matrix used for AK interpolation
MSPEC	Number of species
MI	Index for locating extinction coefficient on tape
N	Frequency index
NAME(3)	ASCII name of next segment to be called
NMAX	Upper limit on index for input of W(N) and AK(K,N) for a particular species
NMIN	Lower limit on index for input of W(N) and AK(K,N) for a particular species
NPT	Number of points in the pressure temperature matrix
NVM(M)	Element in AK(K,N) & W(N) where the Mth Species information begins
NI	Index for locating extinction coefficient
PBAR	Pressure variable (PBAR $\geq$ 75 mb)

PLANK	Black body radiation from BLAM
PP(K)	Pressure array read from tape
PRES(LL)	Pressure at layer LL
RAD	Radiation result
RAD1	Spectral radiation
RV1	Frequency corresponding to information in TRAN1(LL)
RV2	Frequency corresponding to informtion in TRAN2(LL)
SPEC(M,2)	ASCII abreviation of Mth specie
TRAN	Total transmission
TRAN1(LL)	Buffer used to read continuum radiation from disk for layer LL
TRAN2(LL)	Buffer used to read continuum radiation from disk for layer LL
TT(K)	Temperature array read from tape
VA	Initial frequency in tape data block
VB	Final frequency in tape data block
VCHK	Used to compare lower frequency of tape data block with calculation frequency
VCHK2	Used to compare upper frequency of tape data block with calculati frequency
VMAX	Max frequency contained in tape
VMIN	Minimum frequency contained in tape
VO	Initial calculational frequency
V1	Initial calculational frequency
V2	Final calculational frequency
VV(N)	Frequency array read from tape
VV1	Used in interpolating tape input frequencies to calculation frequen
VV2	Used in interpolating tape input frequencies to calculating frequen
WGAS(LL)	Gas concentration
WH20(LL)	Water vapor concentration
WO3(LL)	Ozone concentration
YO	Used in interpolating AK
Z(I)	Altitude

SEGMENT 7

BUF(I)	Buffer containing frequency plus specular radiation and transmission results
IK	Running index for frequency
IRAD	Radiation calculation flag
LEN	Number of frequencies read from disk in one read
NUMV	Total length of V(IK) array
TR(1, IK)	Combined continuum and spectral transmission
TR(2,IK)	Combined continuum and spectral radiation
V(IK)	Frequency corresponding to TR(I,IK)

APPENDIX D

```
      PROGRAM LBL(INPUT,OUTPUT,TAPE2,TAPE4,TAPE5=INPUT)
C
C     8 OCTOBER 76      HITRAN MODIFIED FOR MRDA
C
C
      DIMENSION W(7), GNU(5000), S(5000), ALPHA(5000), EDP(5000)
      DIMENSION MOL(5000),VSTOR(403),STOR(9,304),P(10),T(11)
      DIMENSION CS2(9),OMEGA(201,6),JCALC(6),SO(5000),ALPHAO(5000)
      DIMENSION TI(250,12),ITI(250),SPECIE(7),DENS(6)
      LOGICAL LOGIC
      DATA SPECIE/3HH2O,3HCO2,2HO3,3HN2O,2HCO,3HCH4,2HO2/
C
C
      REWIND 2
      IEOF=0
      DEPTH=0.001
      PI=3.14159
C
      VBLOCK=10.
      BREIT=.06
      BRT2=2.2*BREIT
      SLOWER=1.0E-23
C
      READ(5,76) NPTPTS
   76 FORMAT(I2)
      READ(5,77) (P(I),I=1,NPTPTS)
   77 FORMAT(8(E10.0))
      READ(5,77) (T(I),I=1,NPTPTS)
      PRINT 82,(P(I),I=1,NPTPTS)
   82 FORMAT(* PRESSURE=*,5(2X,F7.2)/10X,5(2X,F7.2))
      PRINT 84,(T(I),I=1,NPTPTS)
   84 FORMAT(* TEMPERATURE=*,5(2X,F7.2)/13X,5(2X,F7.2))
      IF(EOF(5).NE.0) STOP 20
      READ 81, (W(M),M=1,7)
   81 FORMAT(7E10.3)
      PRINT 83
   83 FORMAT(3X,*WATER*,6X,*CO2*,6X,*OZONE*,7X,*N2O *,7X,*CO*,8X,*CH4*,
     1 7X,*O2*,4X)
      PRINT 81, (W(M),M=1,7)
      READ 85, V1,VV2,DV,BOUND
   85 FORMAT(6F10.3)
      PRINT 87, V1,VV2,DV,BOUND
```

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```
   87 FORMAT(* V1 =*,F10.3,* V2 =*,F10.3,* DV=*,F10.3,* BOUND =*,F10.3)
C     WRITE(10,120) V1,VV2,NPTPTS
      WRITE(4,120) V1,VV2,NPTPTS
  120 FORMAT(2(F10.2),I5)
      IF(V1.GE.VV2) STOP 21
C     WRITE(10,130) (P(I),I=1,NPTPTS)
      WRITE(4,131) (P(I),I=1,NPTPTS)
C     WRITE(10,130) (T(I),I=1,NPTPTS)
      WRITE(4,131) (T(I),I=1,NPTPTS)
  130 FORMAT((5(F10.2)))
  131 FORMAT((9(F10.2)))
C
C     .OOP BACK POINT --- READ MORE LINES FROM THE TAPE
  999 V2=V1+VBLOCK
      IF(V2.GT.VV2) V2=VV2
      VBOT=V1-BOUND
      VTOP=V2+BOUND
      VVTOP=VV2+BOUND
C
C     WE ARE NOW READY TO READ TAPE.
C
      I=1
      ITT=1
      NEOF=0
      REWIND 2
1     READ(2)TMIN,TMAX,NIREC,((TI(I1,J1),J1=1,12),ITI(I1),I1=1,NIREC)
      JTO=IOCHEC(2)
      IF(JTO)4,2
4     PRINT 89,GNU(I)
   89 FORMAT(* PARITY ERROR ENCOUNTERED AT*,F12.3)
      GO TO 1
2     IF(EOF(2))5,7
5     IEOF=IEOF+1
      NEOF=NEOF+1
      PRINT 91,IEOF,TMIN,TMAX,NIREC
   91 FORMAT(* END OF FILE ENCOUNTERED*,I5,2F12.3,I5)
      IF(NEOF.GT.2) STOP 22
      GO TO 1
7     NEOF=0
      IF(TMAX.LT.VBOT)GO TO 1
      DO 9 K=1,NIREC
      IF(TI(K,1).LT.VBOT)GO TO 9
      GNU(I)=TI(K,1)
      S(I)=TI(K,2)
      ALPHA(I)=TI(K,3)
      EDP(I)=TI(K,4)
      MOL(I)=ITI(K)
      M=MOL(I)
      SMIN=S(I)*DENS(M)
      IF(SMIN.LE.1.0E-24) GO TO 9
      IF(GNU(I).GT.VVTOP)GO TO 11
      I=I+1
9     CONTINUE
C
C  MAXIMUM NUMBER OF LINES
C
      IF(I.LT.4750)GO TO 1
```

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```
      I=I-1
11    I1=I
      PRINT 97, VBOT,VVTOP,GNU(I1),I1
   97 FORMAT(* VBOT =*,F12.3,*VVTOP =*,F12.3,*GNU =*,F12.3,* I1 *,I8)
C
C     SUPPLY HALFWIDTHS WHEN NOT ON TAPE
C
      DO 15 I=ILL,I1
      MM=MOL(I)
      IF(MM.EQ.1) GO TO 15
      IF(ALPHA(I).GT.0.0) GO TO 13
      IF(MM.EQ.2) ALPHA(I)=0.07
      IF(MM.EQ.3) ALPHA(I)=0.11
      IF(MM.EQ.4) ALPHA(I)=0.08
      IF(MM.EQ.5) ALPHA(I)=0.06
      IF(MM.EQ.6) ALPHA(I)=0.055
      IF(MM.EQ.7) ALPHA(I)=0.08
   13 IF(ALPHA(I).LT.0.01.OR.ALPHA(I).GT.1.0) ALPHA(I)=0.06
   15 CONTINUE
C
C      CALCULATE THE ABSORPTION COEFFICIENTS AT THE 50 MOST INTENSE CO2 LINES
C       AND AT 3 POINTS INBETWEEN
C
C     LOOP BACK POINT  ---  DON'T NEED TO READ TAPE
C
  300 CONTINUE
C     WRITE(10,120) V1,V2
      WRITE(4,120) V1,V2
      DATA DENS/1.0,1.0,1.0E-2,1.0E-3,.5E-3,.5E-2/
      DO 312 JC=1,I1
      IF(GNU(JC).GE.V1) GO TO 313
  312 CONTINUE
  313 IMIN=JC
      DO 314 JC=IMIN,I1
      IF(GNU(JC).GT.V2) GO TO 315
  314 CONTINUE
  315 IMAX=JC-1
C
C
      FAC=1.0E-20
      JLOOP=0
  309 JLOOP=JLOOP+1
      JPTS=0
      FAC=.3*FAC
      IMAX=IMAX+1
      GSTOR=GNU(IMAX)
      SSTOR=S(IMAX)
      MSTOR=MOL(IMAX)
      GNU(IMAX)=V2
      S(IMAX)=1.0
      DO 370 M=1,6
      MOL(IMAX)=M
      OMEGA(1,M)=V1
      SMIN=FAC*DENS(M)
  310 JCNT=1
      DO 320 JC=IMIN,IMAX
      IF(MOL(JC).NE.M) GO TO 320
```

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```
      IF(S(JC).LT.SMIN) GO TO 320
      OLAST=OMEGA(JCNT,M)
      FAC1=20.*GNU(JC)
      IFF=FAC1
      ONEW=IFF/20.
      IF((FAC1-IFF).GT.0.5) ONEW=ONEW+0.05
      IDELT=20.*(ONEW-OLAST)
      IF(IDELT-1) 320,343,344
  343 JCNT=JCNT+1
      GO TO 319
  344 OMEGA(JCNT+1,M)=OLAST+0.05
      IF(IDELT-3) 345,316,317
  345 JCNT=JCNT+2
      GO TO 319
  316 OMEGA(JCNT+2,M)=OLAST+0.10
      JCNT=JCNT+3
      GO TO 319
  317 OMEGA(JCNT+2,M)=.5*(OLAST+ONEW)
      OMEGA(JCNT+3,M)=ONEW-0.05
      JCNT=JCNT+4
  319 OMEGA(JCNT,M)=ONEW
  320 CONTINUE
      JCALC(M)=JCNT
  370 JPTS=JPTS+JCALC(M)
      GNU(IMAX)=GSTOR
      S(IMAX)=SSTOR
      WGL(IMAX)=WSTOR
      IMAX=IMAX-1
      IF((JLOOP.GE.60).AND.(JPTS.GT.240)) GO TO 371
      IF((JPTS.LT.170).AND.(FAC.GE.SLOWER)) GO TO 309
      IF(JPTS.LT.240) GO TO 321
  371 FAC=4.*FAC
      GO TO 309
C
C
  321 CONTINUE
      ICOUNT=0
      DO 240 M=1,6
      JMAX=JCALC(M)
      JNONE=5
      IF(JMAX.GT.JNONE) GO TO 330
C
C
C     NO STRONG LINES IN THIS BLOCK
C
      OMEGA(4,M)=(OMEGA(5,M)+OMEGA(3,M))/2.
      OMEGA(2,M)=(OMEGA(3,M)+OMEGA(1,M))/2.
      PRINT 339,JLOOP,FAC,SPECIE(M),(OMEGA(JJ,M),JJ=1,JMAX)
  339 FORMAT(//* NO INTENSE LINES*,10X,*JLOOP=*,I4,
     $10X,*SMIN=*,E10.3,12X,*SPECIES=*,A10/
     $* OMEGA=*,5F14.3)
      GO TO 338
C
C     STRONG LINES IN THIS BLOCK
C
  330 CONTINUE
      PRINT 325,JMAX,JLOOP,FAC,SPECIE(M)
```

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```
  325 FORMAT (//I10,*  CALCULATIONAL POINTS*,10X,*JLOOP=*,T3,5X,
     **SMIN=*,E10.3,10X,A10/9X,*VALUES OF OMEGA*)
      PRINT 326,(OMEGA(JJ,M),JJ=1,JMAX)
  326 FORMAT(10F10.3)
  338 CONTINUE
      LOGIC=.FALSE.
      IF(M.EQ.1.OR.M.EQ.3.OR.M.EQ.6) LOGIC=.TRUE.
C
C     PRESSURE, TEMPERATURE LOOP
C
C
      P0=1013.00
      T0=296.00
      NPT=0
C
C     BRANCH BACK POINT FOR (P,T) LOOP
C
  350 NPT=NPT+1
      I5=1
      CS1=(T0-T(NPT))/(T0*T(NPT)*0.6946)
C
C     ROTATIONAL PARTITION FUNCTION IS DEFINED BELOW
C
      WT=SQRT(T0/T(NPT))
      CS2(M)=T0/T(NPT)
      IF(LOGIC) CS2(M)=CS2(M)*WT
      CA=WT*P(NPT)/P0
C
C     TEMPERATURE DEPENDENCE OF ALL LINE INTENSITIES COMPUTED HERE.
C
      DO 23 I=ILL,I1
      IF(MOL(I).NE.M) GO TO 23
      SO(I)=S(I)*CS2(M)*EXP(-EDP(I)*CS1)
      ALPHAO(I)=ALPHA(I)*CA
   23 CONTINUE
C
      DO 555 JJ=1,JMAX
      V=OMEGA(JJ,M)
C
      CAV1=0.0
   27 SUM1=0.0
C
C     DETERMINE INDICES (I5 AND I6) INDICATING WHICH SPECTRAL LINES
C     ARE TO BE USED IN THE CALCULATION AT FREQUENCY V.
C
      DO 33 I=I5,I1
      IF (V-BOUND-GNU(I)) 29,29,33
   29 I5=I
      GO TO 35
   33 CONTINUE
      I5=I1
      GO TO 555
   35 DO 39 J=I5,I1
      IF (V+BOUND-GNU(J)) 37,37,39
   37 I6=J-1
      GO TO 43
   39 CONTINUE
```

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```
      I6=I1
C
C     COMPUTE THE OPTICAL DEPTH AND TRANSMITTANCE AT FREQUENCY V.
C
      DV=0.05
   43 DO 45 I=I5,I6
      IF (MOL(I).NE.M) GO TO 45
      Z=V-GNU(I)
      AL=ALPHAO(I)
C     IF(ABS(Z).GE.0.05) GO TO 88
C     IF(AL.GT.0.05) GO TO 88
C
C     ARCTAN FORMULA
C
C     SUM1=SO(I)/DV*(ATAN2(Z+DV/2.,AL)-ATAN2(Z-DV/2.,AL))
C     GO TO 44
C
C     LORENTZ FORMULA
C
   88 SUM1=SO(I)*AL*(.25/((Z-DV/2.)**2+AL*AL)
     &+.50/(Z*Z+AL*AL)+.25/((Z+DV/2.)**2+AL*AL))
   44 CAV1=CAV1+SUM1
   45 CONTINUE
      VSTOR(JJ)=.3183*CAV1*W(M)
  555 CONTINUE
C
      DO 557 JJ=1,JMAX
  557 STOR(NPT,JJ)=VSTOR(JJ)
C
  565 IF (NPT.LT.NPTPTS) GO TO 350
C
C     WRITE MRDA TABLE
C
C     WRITE(10,220) SPECIE(M),JMAX
      WRITE(4,221) SPECIE(M),JMAX
  220 FORMAT(1X,A4,I5)
  221 FORMAT(A4,I5)
      DO 230 JJ=1,JMAX
      ICOUNT=ICOUNT+1
      IF ((ICOUNT.GE.240).AND.(JMAX.NE.2)) GO TO 230
C     WRITE(10,225) OMEGA(JJ,M),(STOR(NPT,JJ),NPT=1,NPTPTS)
      WRITE(4,226) OMEGA(JJ,M),(STOR(NPT,JJ),NPT=1,NPTPTS)
  225 FORMAT(F12.2,4(E12.6)/5(E12.6))
  226 FORMAT(F12.2,9(E12.6))
  230 CONTINUE
  240 CONTINUE
      V1=V1+VBLOCK
      IF(V1.GE.VV2) STOP 23
      VTOP=V1+VBLOCK+BOUND
      IF(VTOP.GT.GNU(I1)) GO TO 999
      V2=V1+VBLOCK
      VBOT=V1-BOUND
      GO TO 300
C
      END
```

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