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GENLN2
A General Line-by-Line Atmospheric Transmittance and Radiance Model

Version 3.0 Description and Users Guide

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PREFACE

This report constitutes the latest documentation for Version 3.0 of the GENLN2 suite of programs as of November 1991.

The need for a new atmospheric transmittance and radiance model at Oxford was recognized by John Eyre of the UK Meteorological Office Unit in the Robert Hooke Institute for Cooperative Atmospheric Research in 1986. At the time, more than 25 members of the Department of Atmospheric Physics and Hooke Institute at Oxford University were engaged in radiative transfer calculations or were direct users of such data. It was decided that there was a strong case for developing a general purpose computation facility which would reduce the time spent duplicating effort in this area. Previously, a general line-by-line code GENLIN had been in use in Oxford. This along with other local codes was found to be limiting and inflexible, and although powerful facilities already existed, for example the Air Force Geophysical Laboratory's FASCODE (*Clough et al.*, 1988), a total re-design to meet current and anticipated needs was considered justified. This would hopefully promote understanding of the physical method and avoid the 'black-box' approach to computer modelling.

The essential computational model was designed first and coded afterwards. The main aims were efficiency of calculation and a clear modular structure so that the model can be easily adapted as a research tool for specific needs. This has taken precedence over speed of computation or loosing sight of the physics in difficult to understand algorithms. The model can then be used in an educational role and enables workers to refine the treatment of one part of the problem in isolation. Conversely, computations may also be performed quickly and without the users having detailed knowledge of the calculation methods involved.

This report is intended to be a working document for those using GENLN2. A separate section is devoted to each of the programs that comprise the GENLN2 suite. Each section begins with a brief overview of the purpose of the program and the physics involved. This is followed by a detailed description of the code structure, required input and code implementation. The appendices include the input and output for two example calculations.

Part of the work presented here was done during the time I held a post-doctoral position in the Satellite Meteorology Group of the Hooke Institute in Oxford. The project has continued since I moved to the Global Atmospheric Change Section of the Atmospheric Chemistry Division at the National Center for Atmospheric Research, Boulder Co.

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1. INTRODUCTION

1.1 Atmospheric Radiative Transfer

Many workers in atmospheric physics and related fields are involved in transmittance and radiance calculations or are direct users of this information. The applications are varied, ranging through remote sensing and satellite meteorology, the measurement of atmospheric constituent gases, comparison calculations with laboratory spectroscopy studies, and developing radiation schemes as a basis for climate models. Calculations are performed over large spectral ranges, from the visible to the microwave, and many radiating gases and atmospheric trace constituents are considered. The physics that must be included has resulted in large and complex computer models.

Although there is great diversity in these calculations, at the heart of each lies an analysis of the effect of absorbing and emitting gases on the propagation of radiation. The computational modelling requirements for widely differing cases have much in common and general purpose radiative transfer models have been developed. For calculations where the detailed spectral structure is important, a high resolution method is necessary. This takes a line-by-line approach where the absorption and emission of radiation by each molecular transition is considered in turn over the spectral range of interest. GENLN2 is a general purpose line-by-line model.

Consider the passage of radiation of wavenumber ν $[cm^{-1}]$ in the z-direction through an element of absorber thickness dz $[cm]$. The radiation attenuation, Fig.1.1, is

$$-dI(\nu, z) = I(\nu, z)\ k(\nu, z)\ \rho_a(z)\ dz, \tag{1.1}$$

where $I(\nu, z)$ is the radiation intensity in $W/(m^2.sr.cm^{-1})$, $\rho_a(z)$ is the absorber number density in $molecules.cm^{-3}$, and $k(\nu, z)$ is the monochromatic absorption coefficient in $1/(molecules.cm^{-2})$.

Integrating this equation from a source point z_s to an observation point z_{obs} gives

$$\int_{I(\nu,z_s)}^{I(\nu,z_{obs})} \frac{-dI(\nu, z)}{I(\nu, z)} = \int_{z_s}^{z_{obs}} k(\nu, z)\ \rho_a(z)\ dz, \tag{1.2}$$

and performing the integral

$$\tau(\nu, z_s, z_{obs}) = \frac{I(\nu, z_{obs})}{I(\nu, z_s)} = \exp\left(-\int_{z_s}^{z_{obs}} k(\nu, z)\ \rho_a(z)\ dz\right), \tag{1.3}$$

where $\tau(\nu, z_s, z_{obs})$ is defined as the transmittance between z_s and z_{obs}.

The element of absorbing gas will also emit radiation, the intensity of which depends on its temperature T in K. If the element were enclosed in a perfectly black box, then the radiation intensity $B(\nu, T)$ in $W/(m^2.sr.cm^{-1})$ entering the gas would be given by the Planck function

$$B(\nu, T) = \frac{c_1 \nu^3}{\exp(c_2 \nu / T)\ -\ 1}, \tag{1.4}$$

where $c_1 = 2\mathbf{hc}^2 = 1.1911 \times 10^{-8}\ \ W/(m^2.sr.cm^{-4})$, $c_2 = \mathbf{hc/k} = 1.439\ K/cm^{-1}$, and $\mathbf{h}$, $\mathbf{k}$ and $\mathbf{c}$ are the Planck constant, Boltzmann constant and speed of light respectively. Thus

from Eqn.(1.1) the absorbed radiation in the z-direction would be $B(\nu,T)k(\nu,z)\rho_a(z)\,dz$. Assuming the gas to be local thermodynamic equilibrium, the temperature must remain constant and it follows from Kirchhoff's law that the radiation intensity emitted in the z-direction will also be

$$B(\nu,T)\ k(\nu,z)\ \rho_a(z)\ dz. \tag{1.5}$$

The total radiative transfer equation will therefore have two parts: a transmitted radiation component which depends on the intensity at z_s and the transmittance from z_s to z_{obs}, and a radiation component due to the emission from all elements dz between z_s and z_{obs} that actually arrive at z_{obs},

$$I(\nu,z_{obs}) = I(\nu,z_s)\,\tau(\nu,z_s,z_{obs}) + \int_{z_s}^{z_{obs}} \Big[B(\nu,T(z))k(\nu,z)\rho_a(z)\,dz\Big]\tau(\nu,z,z_{obs}). \tag{1.6}$$

Solving this radiative transfer equation for the atmosphere is the basic aim of the GENLN2 code.

1.2 The GENLN2 Suite of Programs

The GENLN2 suite of programs (*Edwards*, 1987, 1988) is shown schematically in Fig.1.2. Each of the boxes in bold outline represents a program and the other boxes represent input and output files. In this text, the names of program routines are capitalized. References to files provided with the GENLN2 programs are written in bold lower-case. The programs that will be described in this document are:

HITLIN
This program creates a spectral line data file in the binary form used by GENLN2. The inputs to HITLIN are a user input file to define the task, and one or more line data files in the standard HITRAN (*Rothman et al.*, 1987) format. The output is the GENLN2 line data file.

LAYERS
Program LAYERS performs the atmospheric modelling for GENLN2. The inputs are a file to define the task and an atmospheric profile for temperature, pressure, density and gas mixing ratios. This profile is either supplied by the user or a model profile may be used. The output is a file of *path* data according to the specified geometry of the calculation. A *path* is the basic unit for calculation of optical depth in GENLN2. After the atmosphere has been layered, a ray *path* is defined for each of the gases within the layer. Over the path length the gas is assumed to be homogeneous and average values of temperature, pressure, density and gas amount are calculated.

GENLN2
This program performs the basic line-by-line calculation. The inputs for GENLN2 are the line data file from HITLIN which provides the spectral line parameters for the calculation and the primary user input file to define the task. This primary input file may call on other input files, the path data from LAYERS for example. GENLN2 has two output files. One is a formatted file which contains a summary of the user input and a summary of the output spectra. The second file is the main output for use with the post-processing programs. This is written unformatted and contains all required spectra.

GENGRP
GENGRP is the GENLN2 interactive graphics program. It is set up to select and plot

required spectra. The spectra may be plotted as calculated or degraded by an instrument scanning function. There are options to plot on the same graph other user supplied spectra such as an instrument response function or experimental measurement.

RDOUT
Program RDOUT is a skeleton program to read the GENLN2 unformatted output file. This program can be modified by users to perform any specialized spectral post-processing not carried out by programs GENGRP or BRIGHT.

BRIGHT
Program BRIGHT is an interactive routine to convolve high resolution GENLN2 spectra with a wide-band radiometer response profile supplied by the user. Convolved radiances can also be converted to equivalent brightness temperatures with the aid of a radiance to brightness temperature look-up table .

RADTEM
Program RADTEM is an interactive routine to calculate a radiance to equivalent brightness temperature look-up table for use with program BRIGHT.

1.3 Input File Formats for GENLN2 Input Files

Input to the programs HITLIN, LAYERS and GENLN2 is by means of user supplied input files which define the tasks. The required input parameters for these files will be described in the appropriate sections but the general input system used is described here.

Input parameters on each file are divided between several sections each specified by a *KEYWORD that is recognized by the program. Once a keyword has been read, the program expects certain parameters relevant to the keyword section to follow. Some input sections are mandatory and are required to set up the basic problem. For other input, there may be a choice of keyword sections depending on the required calculation. The following points should be noted:

1. Comments may be included in the file by starting the line with a ! character.
2. Free format input is used throughout, i.e. it is not necessary to input parameters in any particular format and several input parameters may be separated by either a comma or a space.
3. Character input **MUST** be enclosed by quotes.
4. Blank lines in the input file are **NOT** allowed.
5. Certain devices used in the reading of the input file require the records not to be greater than 130 characters long.
6. When file names are supplied in the input files they should not be greater than 80 characters long.

Other input data files have a required format that will be described in the appropriate section. As a general point, comment lines may be included at the top of any input file before the data is read. Comment lines always begin with a ! character.

1.4 GENLN2 Implementation

The GENLN2 suite of programs was originally developed in a VAX/VMS environment. However, the coding is in standard FORTRAN77 with only one extension to standard FORTRAN, the INCLUDE statement. This allows a parameter list of maximum array dimensions to be globally set at the time of compilation. The INCLUDE statement is allowed as an extension under VAX VMS FORTRAN, and as an extension under most UNIX compilers, including the CRAY CFT77 compiler. The parameter statements are set in the file PARRAY, and the statement

as it appears in the code is
INCLUDE 'PARRAY'.

With the exception of program HITLIN all the other GENLN2 programs use the PARRAY file. It has parameter statements which are specific to individual programs and others that are used by several programs. Using the same PARRAY to set maximum array dimensions between different programs ensures compatibility of the different computation stages and should reduce the possibility array dimension errors. The parameters in the PARRAY file that need to be set are described in each program section.

There is one system specific subroutine for the GENLN2 program named TIMER. This returns the accumulated CPU time of a calculation and relies on system specific timer calls. The routine is supplied in skeleton form and the user should modify the routine according the their system.

The VAX VMS COMMAND files and the IBM UNIX *make* files for the compilation, link, assignment of external input/output FORTRAN units and run stages are also supplied with the programs. These are intended as a guide and users who have other systems can use them to write the corresponding job control.

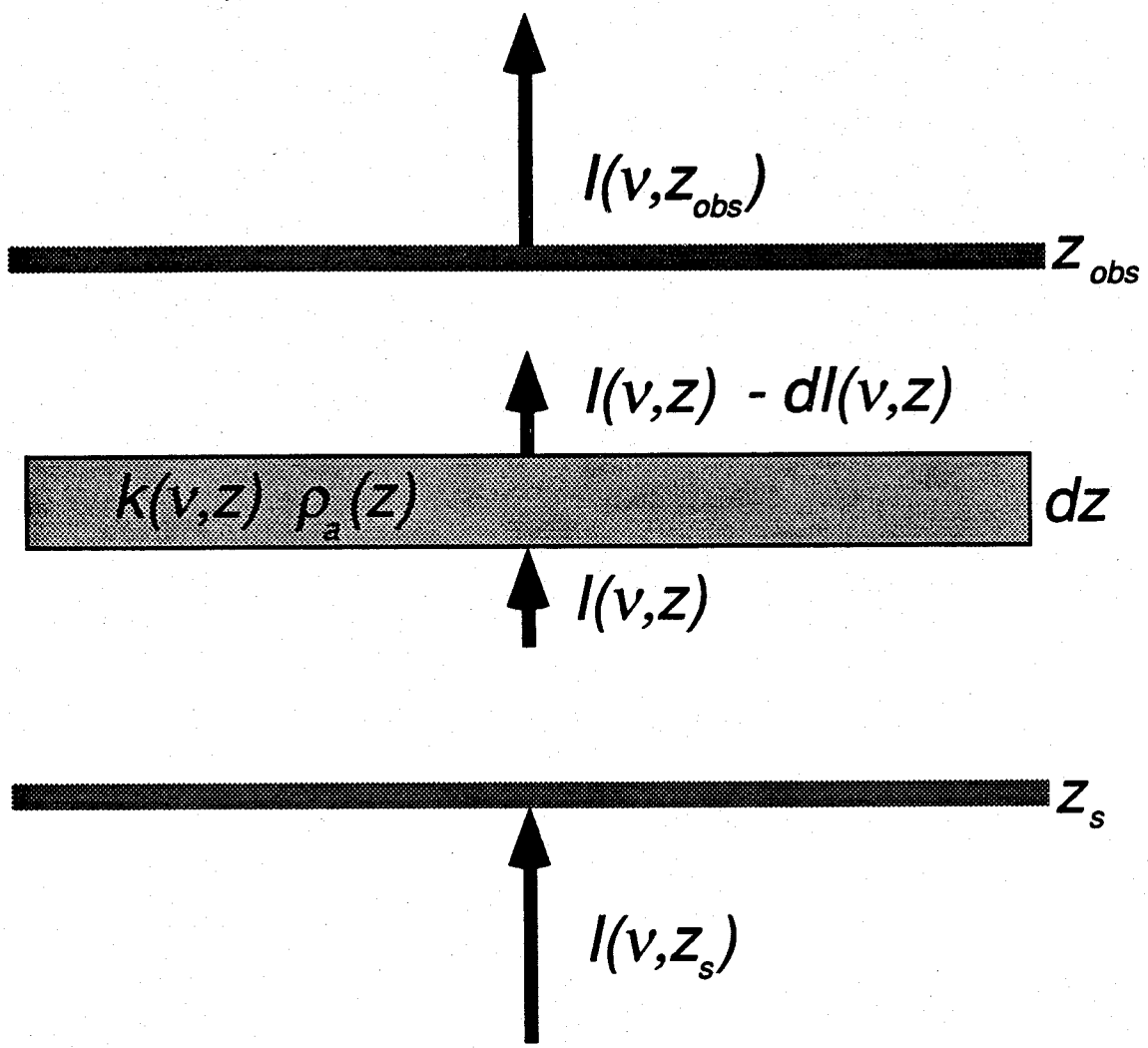


Fig. 1.1
Transmittance of radiation through a slab of absorbing material

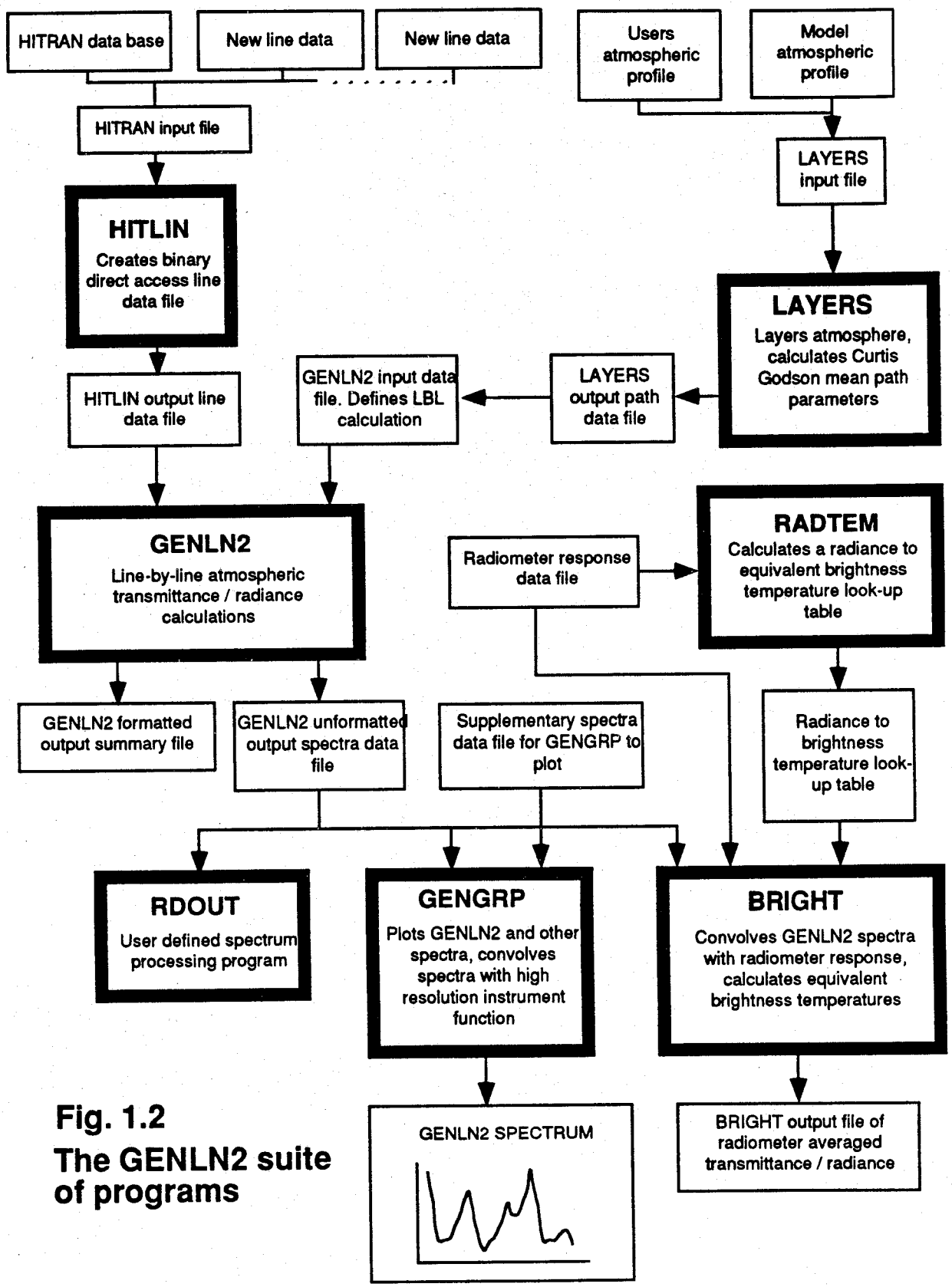


Fig. 1.2
The GENLN2 suite of programs

2. SPECTRAL LINE DATA: PROGRAM HITLIN

2.1 Spectral Line Data Bases

The increasing use of line-by-line radiative transfer codes has been made possible by the availability of comprehensive molecular spectral line data compilations. These draw on the laboratory and atmospheric measurements and calculations of many workers and are periodically up-dated.

There are currently four widely used spectroscopic data bases for use with line-by-line radiative transfer codes. These are the:

GL/HITRAN (Air Force Geophysical Laboratory / High Resolution Transmission) Molecular Absorption Data base (*Rothman et al.*, 1987). The latest edition of the HITRAN data base was released in early 1991, and will be described in a paper by *Rothman et al.* in a special edition of *J. Quant. Spectrosc. Radiat. Transfer* to be published in 1992.

GEISA (Gestion et Etude des Informations Spectroscopiques Atmospheriques) data base (*Husson et al.*, 1986, 1991);

ATMOS (Atmospheric Trace Molecule Spectroscopy) molecular line list compiled for the ATMOS experiment (*Brown et al.*, 1987);

JPL (Jet Propulsion Laboratory) catalogue and atlas of microwave and submillimeter transmission (*Poynter et al.*, 1985).

There has been considerable interaction between the data base managers in recent years and much of the data is common to the various editions. A description of the status of the different compilations can be found in *Husson* (1986).

The HITRAN data base has been adopted for use with the GENLN2 programs. The 1991 edition contains line parameters for 32 molecules, each of which is assigned an ID number as shown in Table 2.1. Also shown are the ID's used with the molecular cross section data sets. These will be discussed in Section 4.4. The HITRAN format is shown in Table 2.2. A table of the HITRAN gases with their different isotopes and relative natural abundances can be found in *Rothman et al.* (1987, and to be published, 1992). It should be noted that the HITRAN line strengths for a particular isotope have been weighted according to the naturally occurring terrestrial abundance of the isotope.

2.2 Overview of Program HITLIN

The program HITLIN has the facility for merging several line data bases to form a single line file that is then used by GENLN2. This is useful for up-dating lines on the HITRAN data base with new line data as it becomes available. The input to the program is a user supplied input file, which is described in detail in Section 2.5, together with one or more line data bases having the HITRAN format.

The HITRAN data base, as distributed, is blocked with 51 lines per record. Before using program HITLIN the data base must be un-blocked so that each line occupies one record.

The program carries out the steps described below.

1. Line records from the input line data bases are first merged together in order of increasing wavenumber between the lower and upper wavenumber bounds specified by the user in the

HITLIN input. A direct access, unformatted output line file is created and the following stages manipulate this new output file. The 1986 version of the HITRAN data base contains 348043 line transitions between 0 and 17900 cm^{-1} and future versions are likely to be considerably larger as more line data becomes available. The option of creating a sub-set of the HITRAN data base will be useful for users with limited on-line storage who are only interested in part of the spectrum.

2. To avoid possible computer underflow problems or very small numbers being set equal to zero, HITLIN scales up the value of the line strength, originally in units of $cm^{-1}/(molecule.cm^{-2})$, by the Avogadro number (6.022×10^{26}). The line strength then has units $cm^{-1}/(kg.mole.cm^{-2})$. In the GENLN2 input file, the gas amounts are stated in units of $kg.mole.cm^{-2}$ to compensate for this scaling. The wavenumber of the transition is also written as a double precision number in the output line file.

3. Each line record is assigned a status number according to which input data base the line came from. These status numbers are defined by the user in the HITLIN input file. If there is more than one input data base and new line data is merged with older data, there may be duplicate lines. These will be distinguished by having different status numbers.

4. Each line record is assigned a forward pointer. This indicates how many lines forward of the current record the next line record occurs for the same gas. This allows lines for any particular gas or set of gases to be accessed directly without reading unwanted line records. This results in a considerable time saving over reading and sorting all lines sequentially during the execution of the GENLN2 line-by-line program.

5. Every 200 line records a forward pointer block is inserted into the line file. This block comprises 3 records that contain the forward pointers to each of the gases on the line file. It ensures that no more than 200 line records will ever be read by GENLN2 in searching for the first occurrence of a line for a particular wanted gas.

6. By comparing the quantum numbers of the line transitions, a check is made for duplicate lines on the output line file. The duplicate lines with the lower status number are flagged by changing the status number to the negative of itself. The input to GENLN2 allows the user to choose which status lines are used in the line-by-line calculation.

2.3 Line Coupling

GENLN2 has the facility for including the effect of spectroscopic line coupling in the line-by-line calculation. This is described in Section 4.3. The line coupling calculation requires a line coupling parameter which is essentially an extra line parameter not included on the HITRAN data base. Rather than modify the HITRAN line data format to include this parameter, the required coefficients for several CO_2 Q-branches are stored in GENLN2 block data subroutine LINMIX. These coefficients are calculated from, and are specific to, a given set of lines since they depend on the line strengths and widths. The file containing the lines for which coupling coefficients have been calculated, **co2mix.dat**, is supplied with the code. These lines contain a flag in the HITRAN REF field to send the code to look for line coupling data when they are read during a GENLN2 calculation. If the line coupling calculation is going to be used then **co2mix.dat** should form the highest status input data base to program HITLIN.

2.4 Description of HITLIN Subroutines

The HITLIN program structure is shown in Fig.2.1.

HITLIN - Main program. This routine performs all the processing stages described above.

HITINP - Subroutine. This routine reads and processes the users input data file which defines the HITLIN task.

2.5 Description of the HITLIN Input File

Input to HITLIN is by means of a user supplied input file. This is assigned to FORTRAN unit number 4 before execution commences. Table 2.3 gives details of the input file and is useful as a reference to the format of the different *KEYWORD sections. The required parameters are indicated and the variable name as used by the code is given. The purpose of the different *KEYWORD sections are described below.

*TITLES

This section is mandatory.
(1A) AHEAD (48 character string) is the title of the HITLIN run. This is used as a header for the output line file and should be descriptive.

*LINDAT

This section is mandatory.
(1A) NFIL (integer) specifies the number of line data bases having the HITRAN format that will be merged to form the unformatted direct access output line file. The maximum number of input data bases is set by a parameter MXFIL in routines HITLIN and HITINP. This currently has the value 5. There then follows NFIL records, one for each input line data file.
(2A) NEWST (integer) is the status number that will be used for labelling lines from this data base.
(2B) FNIN (80 character string) is the file name of the input line data base.

When a new line data base is merged with the HITRAN data base, some lines that have been up-dated may be duplicated. When HITLIN encounters duplicate lines for a given transition, those with the higher status number assume priority. Status numbers should therefore be assigned with new up-dates having higher values. The HITRAN data base will always have the lowest status number and this should be set equal to 10. It is possible to select which version of duplicate lines are used by the GENLN2 line-by-line calculation. This will be described in full in Section 4.10 but for clarity will be mentioned here. A GENLN2 parameter LCHOSE is assigned to each gas. This specifies that for the gas in question and for any given transition, the line version with the highest status will be used by GENLN2 up to and including a line with status LCHOSE.

*RANGES

This input section is mandatory.
(1A) NGAS (integer) gives the maximum number of different gases for which lines will appear on the merged output line file.
(1B) WN1 (real) is the lower wavenumber boundary for selecting lines from the input data bases.
(1C) WN2 (real) is the upper wavenumber boundary for selecting lines from the input data bases. These two parameters allow a subset of the HITRAN data base to be created.

*OUTPUT

This input section is mandatory.
(1A) FNOUT (80 character string) is the file name of the merged, unformatted direct access output line file that will be used by GENLN2.
(2A) MACH (integer) is a machine specifier that determines the record length of the output line file. For a machine that has a 4 byte per word representation and defines the FORTRAN OPEN statement RECL in words, MACH= 1. This is the ANSII standard and is used under VAX/VMS. Other 4 byte per word machines specify the RECL in bytes, eg. IBM/RISC and

MACH= 2. For the CRAY which has an 8 byte per word representation and defines RECL in bytes, MACH= 3. Which ever option is used, the output line file will be specific to the machine type. The same MACH value is also an input parameter for GENLN2 to allow the GENLN2 subroutine HITINI to correctly open the line file.

***ENDINP**
This section is mandatory and signals the end of the input file.

2.6 HITLIN Implementation

The execution of the HITLIN program is performed with the following operations:

1. The HITLIN and HITINP FORTRAN files are compiled and linked.
2. The users input file is assigned to unit 4.
3. The program is executed.

Program HITLIN does not use the PARRAY parameter statement file to set the maximum array dimensions. These are defined in parameter statements in the routines HITLIN and HITINP and described below.

MXLDF - Maximum number of HITRAN format line data bases to be used by program HITLIN. Current value is 5.

MXNEW - Maximum number of lines on any one input data base (excluding the HITRAN line data base). Current value is 15000.

MXRCT - When a new transition record is inserted into the main line data file, MXRCT records are checked either side the new record position for a duplicate transition. Current value is 50.

The input/output FORTRAN unit numbers used by program HITLIN are:

Unit 4. Input
Used for reading the user input file that defines the HITLIN task. This unit number must be assigned outside the FORTRAN program.

Units 10 - (10+NFIL–1). Input
Used for input of the NFIL HITRAN formatted line data bases.

Unit 30. Input/Output
Used for the output unformatted direct access line data file.

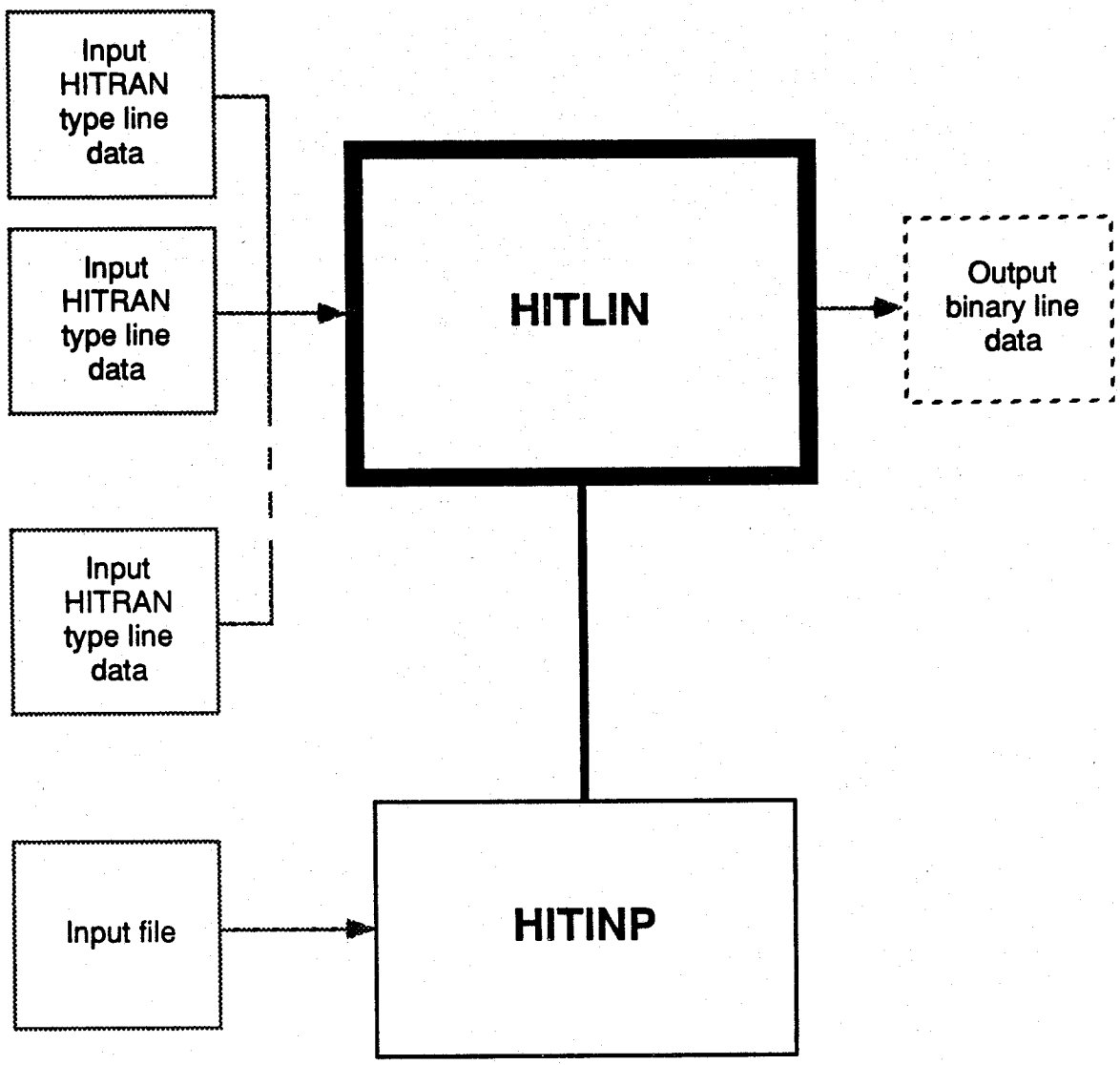


Fig. 2.1

Program structure for the HITLIN subroutines

Table 2.1
Gas molecular ID 's

HITRAN line data		Cross-Section data		
ID	GAS	ID	GAS	
1	H_20	51	$CFCl_3$	(F11)
2	CO_2	52	CF_2Cl_2	(F12)
3	O_3	53	$CClF_3$	(F13)
4	N_2O	54	CF_4	(F14)
5	CO	55	$CHCl_2F$	(F21)
6	CH_4	56	$CHClF_2$	(F22)
7	O_2	57	$C_2Cl_3F_3$	(F113)
8	NO	58	$C_2Cl_2F_4$	(F114)
9	SO_2	59	C_2ClF_5	(F115)
10	NO_2	60	CCl_4	
11	NH_3	61	$ClONO_2$	
12	HNO_3	62	N_2O_5	
13	OH	63	HNO_4	
14	HF			
15	HCl			
16	HBr			
17	HI			
18	ClO			
19	OCS			
20	H_2CO			
21	HOCl			
22	N_2			
23	HCN			
24	CH_3Cl			
25	H_2O_2			
26	C_2H_2			
27	C_2H_6			
28	PH_3			
29	COF_2			
30	SF_6			
31	H_2S			
32	HCOOH			

Table 2.2 Format of the HITRAN line data base

HITRAN

Example line list in the HITRAN format:

```
101  728.236100 8.520E-23 9.063E-06.0630.0000  706.76200.500.000000  2  140 040  +40 139  +084 0 0 0
 21  728.238900 1.850E-25 6.785E-04.0785.1098 2854.68870.750.000000 22 14            P 15 186 0 0 0
101  728.241300 6.850E-24 7.290E-06.0630.0000 1180.57700.500.000000  2  149 446  +48 543  +084 0 0 0
 31  728.244500 2.400E-22 0.000E+00.0758.0000  100.57240.760.000000  2  116 214   15 115   000 0 0 0
 31  728.245700 2.450E-23 0.000E+00.0618.0000 1425.03870.760.000000  3  243 143   42 042   000 0 0 0
121  728.247180 2.670E-23 0.000E+00.1300.0000  596.99000.500.000000 30 14382216   392316   000 0 0 0
121  728.247180 2.670E-23 0.000E+00.1300.0000  596.99000.500.000000 30 14382316   392416   000 0 0 0
211  728.248000 2.117E-21 4.000E+00.0600.0000    5.97000.500.000000  5  1 4 0 4    3 0 3   000 0 0 0
211  728.248300 1.803E-21 3.750E+00.0600.0000   25.97000.500.000000  5  1 4 1 3    3 1 2   000 0 0 0
 31  728.259800 1.280E-25 0.000E+00.0618.0000 2243.33350.760.000000  3  260 357   60 258   000 0 0 0
 24  728.261500 4.470E-27 2.092E-03.0559.0606 2388.56340.750.000000  2  1             R 79 186 0 0 0
 31  728.266100 1.780E-23 0.000E+00.0618.0000  775.32160.760.000000  3  2 7 5 3    7 4 4   000 0 0 0
101  728.267300 2.250E-23 1.726E-05.0630.0000 1113.25900.500.000000  2  150 149  -50 248  -084 0 0 0
 25  728.267800 1.120E-26 3.718E-04.0646.0821 1247.44140.750.000000  5  2             R 40 186 0 0 0
101  728.271400 6.710E-24 7.140E-06.0630.0000 1180.56600.500.000000  2  149 446  -48 543  -084 0 0 0
 31  728.272300 1.170E-24 0.000E+00.0618.0000 1565.91950.760.000000  3  246 145   46 046   000 0 0 0
 31  728.275500 9.300E-24 0.000E+00.0758.0000 1221.74800.760.000000  2  153 450   53 351   000 0 0 0
101  728.277200 8.310E-23 8.840E-06.0630.0000  706.78300.500.000000  2  140 040  -40 139  -084 0 0 0
```

QUANTITES AND FORMATS READ FROM HITRAN FORMAT LINE DATA BASE

VARIABLE	FORMAT	DESCRIPTION
IGAS	I2	Molecule ID number
ISO	I1	Isotope number (1=most abundant, 2=second,)
WNUM	F12.6	Line wavenumber [cm-1]
STREN	E10.3	Line strength [cm-1/(molec.cm-2)]@ 296K
TPROB	E10.3	Transition probability [Debyes2]
ABROAD	F5.4	Air-broad half width (HWHM) [cm-1/atm]@ 296K
SBROAD	F5.4	Self-broad half width (HWHM) [cm-1/atm]@ 296K
ELS	F10.4	Lower-state energy [cm-1]
ABCOEF	F4.2	Coefficient of temperature dependance of air-broadened half width
TSP	F8.6	Transition shift due to pressure (now empty)
IUSGQ	I3	Upper state global quanta index
ILSGQ	I3	Lower state global quanta index
USLQ	A9	Upper state local quanta
BSLQ	A9	Lower state local quanta
AI	3I1	Accuracy indices for frequency, intensity and half width
REF	3I2	Indices for lookup of references for frequency, intensity, and half width

Total = 100 characters per transition

QUANTITES WRITTEN FOR THE HITLIN OUTPUT BINARY LINE DATA FILE

VARIABLE	TYPE	DESCRIPTION
LSTAT	Int	Status number of transition
IGAS	Int	Molecule ID number
ISO	Int	Isotope number (1=most abundant, 2=second,)
WNUM	DblP	Line frequency [cm-1] in double precision
STREN	Real	Line strength [cm-1/(kg.mole.cm-2)] @ 296K (HITRAN value * 6.022E26 to avoid underflows)
TPROB	Real	Transition probability [Debyes2]
ABROAD	Real	Air-broad half width (HWHM) [cm-1/atm] @296K
SBROAD	Real	Self-broad half width (HWHM) [cm-1/atm] @296K
ELS	Real	Lower-state energy [cm-1]
ABCOEF	Real	Coefficient of temperature dependance of air-broadened half width
TSP	Real	Transition shift due to pressure
IUSGQ	Int	Upper state global quanta index
ILSGQ	Int	Lower state global quanta index
USLQ	A*9	Upper state local quanta
BSLQ	A*9	Lower state local quanta
AI	A*3	Accuracy indices for frequency, intensity and half width
REF	A*6	Indices for lookup of references for frequency, intensity, and half width
IFWDPT	Int	Forward pointer to next record for this gas

Table 2.3 Program HITLIN reference input file

hitlin_input.ref

```
!            ***********************************************
!            *                                             *
!            *          PROGRAM HITLIN: INPUT FILE         *
!            *          --------------------------         *
!            *  PROGRAM TO CREATE A BINARY LINE DATA BASE  *
!            *  FROM ONE OR MORE LINE DATA FILES IN THE    *
!            *  HITRAN FORMAT. THE BINARY FILE IS IN THE   *
!            *  REQUIRED FORM FOR GENLN2.                  *
!            *  VERSION 3.0:  D.P. EDWARDS 26/03/90        *
!            *                                             *
!            ***********************************************
!                                                          INPUT PARAMETER NAME
!-----------------------------------------------------------------------------
!..TITLE LABEL FOR THIS HITLIN RUN (*TITLES) [MANDATORY]
*TITLES
!
!  1A. Title label of this HITLIN run :                                  AHEAD
AHEAD
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..LINE DATA FILES (*LINDAT) [MANDATORY]
*LINDAT
!
!  1A. No of formatted line data files (HITRAN format)                   NFIL
NFIL
!
!  For each line data file, 1 record (IFIL=1,NFIL)
!  2A. Status number for lines on file IFIL:                        NEWST(IFIL)
!  2B. Filename of line data file:                                   FNIN(IFIL)
NEWST(1), FNIN(1)
NEWST(2), FNIN(2)
          |
NEWST(NFIL), FNIN(NFIL)
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..FREQUENCY RANGE FOR OUTPUT (*RANGES) [MANDATORY]
*RANGES
!
!  1A. Maximum number of different gases on output file:                 NGAS
!      (32 for HITRAN gases only)
!  1B. Lowest wavenumber for output file:                                 WN1
!  1C. Highest wavenumber for output file:                                WN2
NGAS, WN1, WN2
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..OUTPUT FILE (*OUTPUT) [MANDATORY]
*OUTPUT
!
!  1.A File name of the binary output line file to be used by GENLN2:   FNOUT
FNOUT
!
!  2.A Machine specifier, determines record length:
!      MACH=1: 4 byte/word machine, OPEN RECL in words (eg. VAX, ANSII stand)
!      MACH=2: 4 byte/word machine, OPEN RECL in bytes (eg. IBM RISC)
!      MACH=3: 8 byte/word machine, OPEN RECL in bytes (eg. CRAY)
MACH
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..END OF HITLIN INPUT (*ENDINP) [MANDATORY]
*ENDINP
!!!!!!!! End of section !!!!!!!
```

3. ATMOSPHERIC MODELING: PROGRAM LAYERS

3.1 Layers, Paths, and Mixed Paths

The definitions of *layers*, *paths* and *mixed paths* are important for understanding the GENLN2 calculation procedure. These quantities will be defined here and used in the following discussions.

Layers
The inhomogeneous nature of the atmosphere along a radiation path is most readily treated by sub-dividing the atmosphere into a set of layers. In this way the integration over z in Eqn.1.6 becomes a summation over the constituent layers. The layer boundaries should be chosen in such a way that the gas within the layer may be considered homogeneous and well represented by appropriate Curtis-Godson absorber weighted mean parameters for temperature and pressure. In spherical geometry the layers may be thought of as concentric shells. In a plane-parallel atmosphere the layers take the form of horizontal slabs as shown in Fig.3.1.

Paths
Within each layer a series of single gas *paths* are defined. A path is defined along the actual ray trajectory within the layer for each of the different gases comprising the layer. Since the gas within the layer is homogeneous, a path forms the basic unit for the calculation of optical depth.

Mixed Paths
GENLN2 calculates the optical depths for each of the single gas paths within each layer and these are stored individually. The path optical depths are later combined, or *mixed*, to obtain multi-gas optical depths and optical depths over several layers according to the problems being addressed. A mixed path is therefore defined as the combination of several paths either within the same layer or across different layers. By keeping the single gas path optical depths separate, several different mixed path calculations that use the same basic set of path optical depth components can be performed by GENLN2 in parallel.

Consider the simple example of Fig.3.1. One mixed path that might be of interest could be formed from the combination of paths 6, 7, 8, 9, and 10 to obtain a mixed path representing the passage of radiation through the CO_2 component of the atmosphere alone. By summing the optical depths of these paths the total CO_2 optical depth is formed. Another calculation might be the combination of paths 4, 9, and 14 to obtain a mixed path representing the passage of radiation through all the gases of layer 4. By summing the optical depths of these paths the total optical depth of layer 4 is obtained.

3.2 Overview of the Program LAYERS

The main purpose of the LAYERS program is to calculate a set of mean gas parameters; temperature, pressures and gas amount, for each of the single gas paths defined by the user input. The output path file from LAYERS is in a format that can be read directly by GENLN2. The line-by-line calculations then proceed for each of the paths.

The LAYERS calculation of an atmospheric path file is kept as a pre-processing stage to GENLN2 so that users who are interested in performing line-by-line simulations of laboratory experiments can go straight into GENLN2 and miss the LAYERS calculation. Experience has also shown that the same set of path data may be required for several different GENLN2 calculations and the ability to store a path file for future calculations has been useful.

3.3 Atmospheric Profiles

The atmospheric profile that is going to be used for the LAYERS calculation can be supplied by the user or taken from one of six zonal and seasonal averaged model profiles (*Anderson et al.*, 1986). These are provided on file **glatm.dat**. The program also allows the user's profile, if used, to be merged with the model profile when necessary data is missing from the former. The program requires vertical atmospheric profiles for pressure [*mb*], temperature [*K*], air density [$molecules.cm^{-3}$], and gas mixing ratios [*ppmv*] for each of the gases specified in the input file. The users file is first searched for the mixing ratio profile of a required gas and if it is not present the specified model profile is used. There is also the option to continue the users profile to higher altitudes using the model profile. This is especially useful for continuing experimentally determined mixing ratio data. A vertical profile for the refractive index is calculated from the temperature and pressure profiles. The equation for calculating the index of refraction is taken from *Elden* (1966).

Altitude in *km* is the vertical variable used by LAYERS. If the atmospheric profiles are supplied at pressure levels, then a corresponding height must be calculated. This is done using the hydrostatic equation taking into account the dependence of air molecular weight on humidity and the variation of gravitational acceleration with altitude and latitude.

3.4 Atmospheric Layering

The atmospheric layer boundaries may be supplied by the user or alternatively, an optimal set of boundaries are calculated based on a maximum allowed variation of temperature and average Voigt line half width across a layer. The maximum variations of temperature across the lowest and highest layers are supplied by the user. The allowed temperature variation at middle altitudes is determined by exponentially interpolating between these two values. The choice of temperature variation will depend on the viewing geometry and the required accuracy. It allows a finer layer structure to be calculated at lower altitudes and in the region of a temperature inversion. As a guide, the variation in the lowest layer should be a few degrees, less than 5 K, and for most applications, it can be around 20 K for the top layer. The temperature condition determines the accuracy of the GENLN2 radiance calculation. This is dependent on the evaluation of the Planck function at the mean layer temperature which should be representative of the temperature variation within the layer. The fractional variation of Voigt half width across a layer is also set by the user and should have a value between 1 and 2. This condition ensures the accuracy of the transmittance calculation. For some applications it may be necessary to perform sensitivity calculations to ensure that the optimum number of layers is being used for the desired accuracy and speed of computation.

Since the transmittance weighting functions for limb viewing geometries peak near the tangent point, it is important that a fine layer structure be used in this region. A vertical layer thickness of 1 *km* or less is suggested for the lowest layer.

Once the layer structure has been determined, a path is defined for each of the required gases within the layer. The parameters required to define the ray trajectory over the path are the layer boundary altitudes and the local zenith angle at the lower layer boundary, see Fig.3.2. The initial ray zenith angle at the lower boundary of the atmosphere is supplied by the user. The local zenith angle θ at the lower boundary of each layer is then calculated by the code according to Snell's law

$$c = n(r) r \sin\theta, \tag{3.1}$$

where c is a constant along the ray path and $n(r)$ is the refractive index of air at a radius r from the Earth's center.

When the ray paths have been fully defined, the Curtis-Godson absorber weighted mean values are calculated for each path j. The integrated absorber amount u_j for the ray path s between the vertical layer boundary heights z_{l_-} and z_{l_+} is

$$u_j = \int_{z_{l_-}}^{z_{l_+}} \left(\rho_a(z)_j \frac{ds}{dz}\right) dz \tag{3.2}$$

where $\rho_a(z)_j$ is the local number density of gas j. The mean values for the path pressure p_j and temperature T_j are

$$p_j = \frac{1}{u_j} \int_{z_{l_-}}^{z_{l_+}} p(z) \left(\rho_a(z)_j \frac{ds}{dz}\right) dz; \qquad T_j = \frac{1}{u_j} \int_{z_{l_-}}^{z_{l_+}} T(z) \left(\rho_a(z)_j \frac{ds}{dz}\right) dz. \tag{3.3}$$

In this way, slightly different values for the layer mean temperature and pressure are obtained for each path gas. The layer is sub-divided into several thinner layers in order to perform the in-layer ray tracing and integration. The algorithm used is similar to that used in the LOWTRAN7 code (*Kneizys et al.*, 1988). The temperature and gas mixing ratio are assumed to vary linearly between the layer boundaries, whilst the pressure and density are assumed to vary exponentially.

The LAYERS program is set up to perform ray tracing in the Earth's atmosphere. The calculation of the hydrostatic equation and the refractive index are specific to the Earth. If the program is to be used for layering the atmosphere of a different planet then several modifications will be necessary. The calculation of the Earth's radius and refractive index in subroutine REFRAC will need to be changed, as will the calculation of the gravitational constant in subroutine PRESHT. The lines of code requiring change are indicated by comments in the routines. The atmospheric profiles will have to be supplied in full.

Fig.3.2 defines the geometry of the LAYERS calculation. For a nadir or zenith viewing problem the local zenith angle θ at any layer will be zero. For a limb viewing calculation $\theta_0 = 90°$ at the tangent point and decreases with altitude. For a spherically symmetric atmosphere the transmittances in layers either side the tangent point are identical and path parameters are only required from the tangent point to space. The total transmittance from space to the tangent point and back to space again can be formed as a mixed path in the GENLN2 calculation by doubling the calculated path optical depths from the tangent point to space. If a limb path through a non-symmetrical atmosphere is required, the LAYERS program should be run twice, once with the atmospheric profile relevant to the ray path from space to the tangent point and once with the profile for use with the ray path from the tangent point to space. This will produce two paths files for use with the GENLN2 input. The calculated path optical depths can then be combined in GENLN2 as required.

The angle parameters defining the refracted ray path are shown in Fig.3.2. These quantities are also written to the path output file. Each path j is defined by the zenith angle at the lower layer boundary θ_j, the path Earth-centered angle β_j, the path bending angle Ψ_j, the zenith angle at the upper layer boundary ϕ_j, and the path length within the layer PL_j. For each of the gases for which refractive ray paths are calculated through the atmosphere, the total column amount, total ray path length PL_{tot}, total Earth-centered angle β_{tot}, and total ray path bending angle Ψ_{tot} are also given.

3.5 Description of LAYERS Subroutines

The LAYERS program structure is shown in Fig.3.3.

LAYERS - Main program. Management program for the calculation.

LAYDAT - Block data subroutine. Initializes input/output unit numbers and physical constants that are used in the calculation.

LAYOT1 - Subroutine. Opens the output path data file in readiness for any error messages that will be written during program execution.

LAYINP - Subroutine. Reads the user supplied input file defining the LAYERS task. It interprets the *KEYWORD input options and reads data.

PROFIL - Subroutine. Creates the atmospheric profile arrays that will be used. It reads a profile supplied by the user and the specified model profile. If required, the profiles are merged.

REFRAC - Subroutine. Calculates the radius of the Earth at the location of the atmospheric profile, and forms a vertical refractive index profile at the same altitude levels as the pressure and temperature profiles.
PLANET SPECIFIC routine.

PRESHT - Subroutine. Uses the hydrostatic equation to calculate the heights corresponding to the pressure levels of the users atmospheric profile when the latter is given at pressure levels only. The variation of air molecular weight with humidity and the variation of gravitational acceleration with latitude and altitude are considered.
PLANET SPECIFIC routine.

INTEG - Subroutine. General purpose numerical routine to calculate a weighted integration using Simpsons rule.

INTER - Subroutine. General purpose numerical interpolation routine for interpolating between two arrays at a supplied argument value. Several interpolation options are available.

LAYCAL - Subroutine. Defines the layer and path structure of the LAYERS calculation. Layer boundaries are either taken from the user input or an optimum layer structure is calculated by AUTLAY. Single gas paths are then defined by the layer boundary heights and lower layer boundary zenith angle.

AUTLAY - Subroutine. Calculates an optimum layer structure for the pressure and temperature profiles based on a maximum allowed variation in Voigt line half width and temperature across a layer.

WIDTH - Subroutine. Calculates an average Voigt line half width.

CURGOD - Subroutine. Checks and organizes the path input parameters to the ray-tracing routine RAYTCE.

RAYTCE - Subroutine. Performs the ray-tracing of the radiation along each path and calculates Curtis-Godson absorber weighted mean path values for temperature, pressure, partial pressure and absorber amount. The layer width is sub-divided onto a finer sub-layer structure for the ray-tracing and integration.

LAYOT2 - Subroutine. Writes the LAYERS output path file. This is written in the required format for reading by the GENLN2 subroutine PTHFIL.

LEVELS - Subroutine. Writes a summary of the layer structure used in the LAYERS calculation to the output path data file.

3.6 Description of the LAYERS Input File

Input to LAYERS is by means of a user supplied input file in the format described in Section 1.3. This is assigned to FORTRAN unit number 4 before execution commences. Table 3.1 gives details of the input file. The purpose of the different *KEYWORD sections is described below.

***TITLES**
This section is mandatory.
(1A) TITLEP (80 character string) is the title of the LAYERS run. This is used as a header for the output path file and should be descriptive.

***USEPRO**
This section should be supplied if and only if *MODPRO is not supplied, in which case it is mandatory. *USEPRO contains the input for the user's atmospheric profile to be used in the LAYERS calculation.
(1A) FNPROF (80 character string) is the file name of the user's profile data set. The profile data should be arranged and have the units of the example shown in Table 3.2. This table illustrates the description below.
Header records:
The profile file may have title header records beginning with the ! character. These records will be printed in the LAYERS output file so they should be fully descriptive of the profile. The input parameters in the records that follow are read free format.
First input record:
The first parameter is the character 'H' or 'P'. This specifies whether the profile will be supplied at Height levels or at Pressure levels. The second parameter is the number of profile levels that follow (92 in this case). The third parameter is the number of gas mixing ratio profiles supplied (8 gas profiles here).
Second input record:
A list of the molecular ID's of the gases for which mixing ratio profiles are supplied (8 profiles, gas ID's 1 (H_2O), 3 (O_3), 4 (N_2O), 5 (CO), 6 (CH_4), 8 (NO), 10 (NO_2), and 12 (HNO_3)).
Third input record:
The first parameter is the Earth latitude where the profile was taken (30°in this case) and the second parameter is the height in *km* of the first profile point (9.5 *km*).
Profile records:
There then follows a record for each of the profile levels (92 here). If the profile is defined at height levels 'H' the first parameter is the level height in *km*. This parameter is absent if the profile is defined at pressure levels 'P'. Then come the level pressure in *mb*, the level temperature in *K* and the total gas number density in $molecules.cm^{-3}$. The volume mixing ratios in *ppmv* for each of the gases specified in the second input record then follow in turn (*ppmv* of H_2O followed by *ppmv* of O_3 and so on through to *ppmv* of HNO_3).

If the profile is supplied at pressure levels, corresponding altitudes are calculated by the code in routine PRESHT.

Returning now to the main input file, Table 3.1.
(2A) FNAFGL (80 character string) is the name of the file containing the model atmospheres being used. These are used to provide other gas mixing ratio profiles that are not present in

the user's profile. The set of Air Force Geophysical Laboratory model atmospheres (Anderson et al., 1986) are provided in the file **glatm.dat**.
(3A) MONO (integer) is the the number identifying the model atmosphere to be used.
(4A) WADD (logical) when set to .TRUE. causes the user's gas mixing ratio profile to be supplemented from the model profile if the former falls to zero at any of the profile levels. This is often useful when using an atmospheric profile where the water vapor radiosonde runs out at a low altitude.
(4B) TOPADD (logical) when set to .TRUE. causes the model profile to be appended to the top of the user's profile if layers are required at altitudes higher than the highest level of the user's profile.

***MODPRO**
This section should be supplied if and only if *USEPRO is not supplied, in which case it is mandatory.
(1A) FNAFGL (80 character string) is the name of the file containing the model atmospheres as described in the *USEPRO section.
(2A) MONO (integer)is the number identifying the model atmosphere to be used.

***SUBLAY**
This section is mandatory.
(1A) NP (integer) determines the number of sub-layers used in performing the Curtis-Godson path integrations. The width of a sub-layer Δl is given by

$$\Delta l = \frac{\Delta L}{\mathrm{NP}} \times \cos\theta \tag{3.4}$$

where ΔL is the total layer width and $\cos\theta$ is the cosine of the local zenith angle. A value of around 10 should be adequate.
(1B) LREF (logical) is a switch which when set to .TRUE. includes atmospheric refraction in the calculation.

***FREQCY**
This section is mandatory.
(1A) V1 (real) is the lower wavenumber of the spectral range for the proposed GENLN2 calculation.
(1B) V2 (real) is the upper wavenumber of the spectral range for the proposed GENLN2 calculation. The mean value of V1 and V2 is used in determining the refractive index profile and the Voigt half width for the optimal layering option.

***USELAY**
This section should be supplied if and only if *DEFLAY is not supplied, in which case it is mandatory. It allows the user to define the layer boundaries to be used by the LAYERS calculation.
(1A) COOR (1 character) specifies whether the layer boundaries will be given at height 'H' or pressure 'P' levels.
(1B) NOLAY (integer) is the number of layers for calculation.
(1C) NOGAS (integer) is the number of different path gases in each layer.

The output path file written by LAYERS is in a format for direct input into GENLN2. Therefore several other path input parameters that are required as part of the path data input to GENLN2 must be specified at this stage. There follows a record for each of the NOGAS different path gases for the calculation.
(2A) IFILE (integer) identifies the line data file to be used for paths of this gas. GENLN2 is able to access several line data files in the HITLIN output form during the line-by-line calculation since it is sometimes convenient to be able to read line data for different gases

from different line files.
(2B) LISTG (integer) is the molecular ID of the gas.
(2C) LISTI (integer) is the HITRAN isotope abundance ID. This is defined as follows; for LISTI= 0 lines of all isotopes of the gas are considered, for LISTI= 1 lines of the 1st most abundant isotope are taken, and so on.
(2D) SHAPE (8 character string) is the line shape that will be used during the line-by-line calculation for paths of gas LISTG. The various options will be described in Section 4.10.
(2E) CNTM (8 character string) is the path input parameter used to specify if a continuum calculation is to be performed for the path. This takes the values 'CON' or 'NOCON'.
(2F) MLANG (integer) is the layer number, the lower boundary height of which will be added to the Earth's radius to form the radius r in Eqn.(3.1). This is then used in the initial calculation of the ray-path refraction constant c.
(2G) THETAL (real) is the value of the local zenith angle θ in degrees of the ray path at the lower boundary of layer MLANG. The same value of c is then used for all paths of a particular gas. Since the height of the layer lower boundary of each path will be defined, this allows the path local zenith angle to be calculated.

For each of the NOLAY layers there follows one record of input containing:
(3A) ILAY (integer) the layer number.
(3B) XLL (real) the lower layer boundary level in km if COOR='H' or in mb if COOR='P'.
(3C) XLU (real) the upper layer boundary level in km if COOR='H' or in mb if COOR='P'.

***DEFLAY**
This section should be supplied if and only if *USELAY is not supplied, in which case it is mandatory. It allows the layer boundary heights to be internally calculated by the code.
(1A) WDIF (real) is the maximum allowed fractional variation factor for an average Voigt half width across a layer. This value should be between 1 and 2.
(1B) TDIFB (real) is the maximum allowed variation of temperature in K across the lowest atmospheric layer.
(1C) TDIFT (real) is the maximum allowed variation of temperature in K across the highest atmospheric layer.
The Voigt half width is calculated for a representative gas of molecular weight 36 and air-broadened half width at 1 atm and 296 K of 0.1 cm^{-1}. The allowed temperature variation at some intermediate altitude is obtained by exponentially interpolating between TDIFB and TDIFT.
(2A) COOR (1 character) specifies whether the atmosphere boundaries will to be given at height 'H' or pressure 'P' levels.
(2B) NOGAS (integer) is the number of different path gases to be included in each layer.

As with the *USELAY option, several path input parameters that are required as part of the path data input to GENLN2 must be specified at this stage. There follows a record for each of the NOGAS different path gases for the calculation.
(3A) IFILE (integer) identifies which line data file should be used for paths of this gas.
(3B) LISTG (integer) is the molecular ID of the gas.
(3C) LISTI (integer) is the HITRAN isotope abundance ID. This is defined as follows; for LISTI= 0 lines of all isotopes of the gas are considered, for LISTI= 1 lines of the 1st most abundant isotope are taken, and so on.
(3D) SHAPE (8 character string) is the line shape that will be used during the line-by-line calculation for paths of gas LISTG.
(3E) CNTM (8 character string) is the path input parameter used to specify if a continuum calculation is to be performed for the path.
(4A) ALL (real) is the atmosphere lower boundary height.
(4B) ALU (real) is the atmosphere upper boundary height. The layering will be performed

between ALL and ALU. These parameters are given in *km* if COOR='H' or in *mb* if COOR='P'. (4C) THETAA (real) is the value of the initial ray zenith angle at the lower atmospheric boundary. This is required for the calculation of the Snell's law ray-path constant c and is the same as the θ_0 parameter in Fig.3.2. It takes the value of 0° for a nadir view or 90° for a limb viewing geometry.

***LEVELS**
When specified this section sets a logical switch that causes a summary of the layer structure to be written at the end of the output path file.

***ENDINP**
This section terminates the LAYERS input file and is mandatory.

3.7 LAYERS Implementation

The execution of the LAYERS program is performed with the following operations:

1. Program LAYERS and its subroutines are compiled and linked.
2. The users input file is assigned to FORTRAN unit 4 and the output line data file is assigned to unit 30.
3. The program is executed.

Program LAYERS uses the PARRAY parameter file to set the maximum array dimensions. An example of the file is shown in Table 3.3. The first section refers specifically to the LAYERS program.

MXPRO - Maximum number of levels in the model or user's profile. For the set of model profiles this is 50.

MXMOL - Highest molecular ID used in the calculation. It is safest to set this to the current highest value, including the cross-section molecular ID's, which is 63.

MXPTH - Maximum number of paths that will appear on the output path data file. This will be equal to the *number of layers* × *the number of gases per layer.* If *DEFLAY is chosen the number of layers will be unknown at the start of the calculation so a large value should be used.

The input/output FORTRAN unit numbers used by program LAYERS are:

Unit 4. Input
Used for reading the input file that defines the LAYERS task. This unit number must be assigned outside the FORTRAN program. This unit is also used for reading the atmospheric profile data sets.

Unit 30. Output
Used for the output of the LAYERS path file.

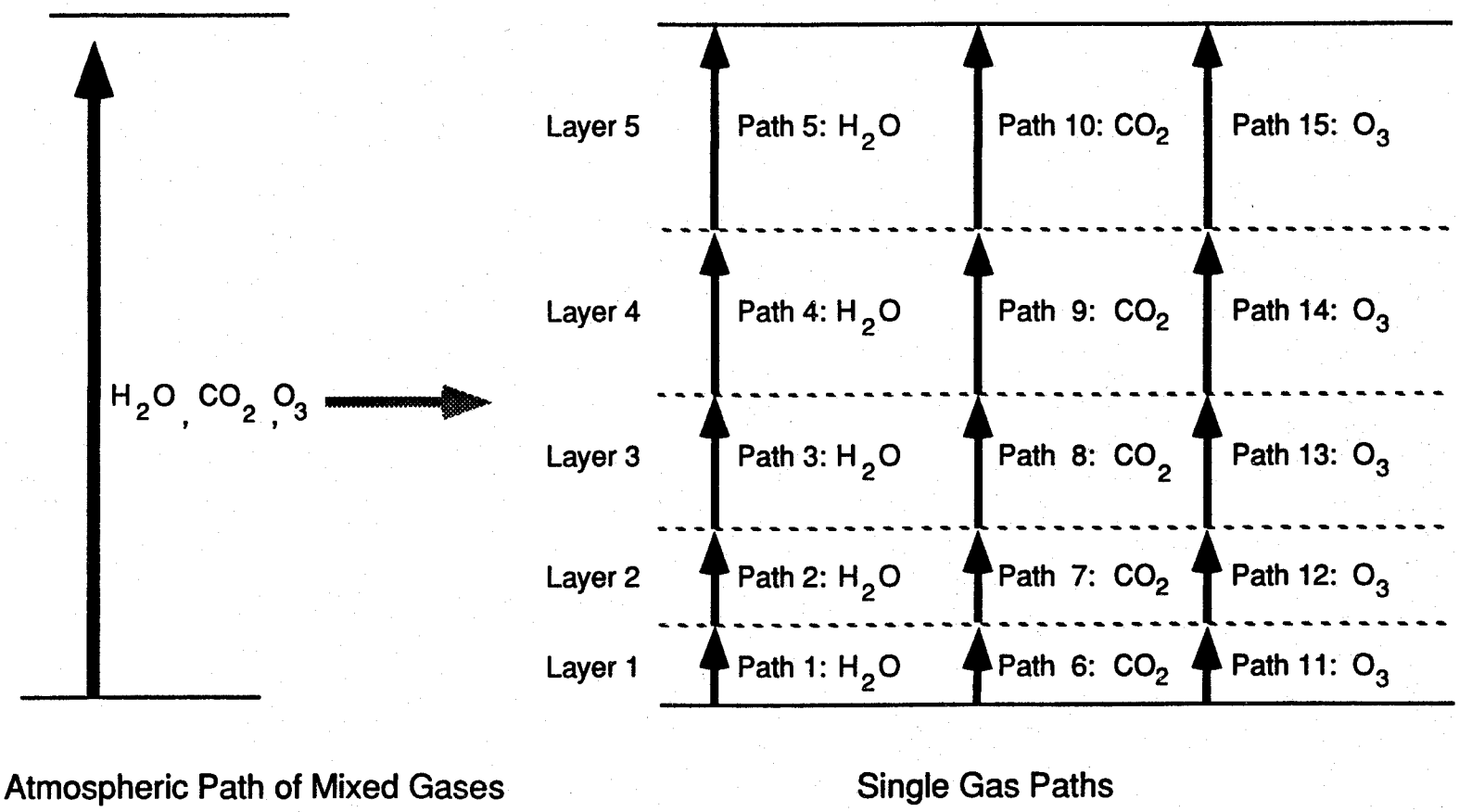


Fig. 3.1
Decomposition of an atmospheric path of mixed gases into layers and single gas paths

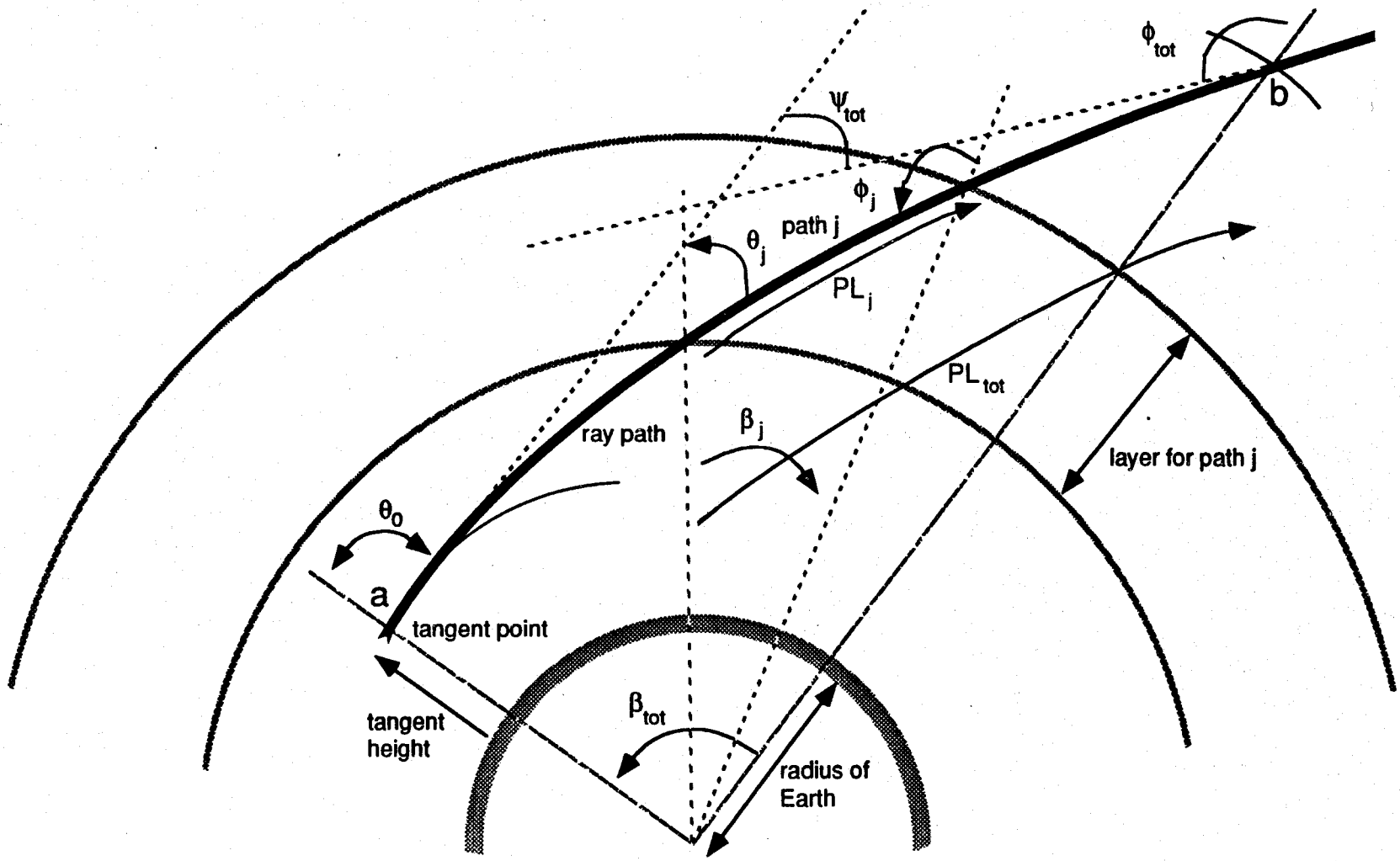


Fig. 3.2

Geometry of a limb path through a refractive atmosphere

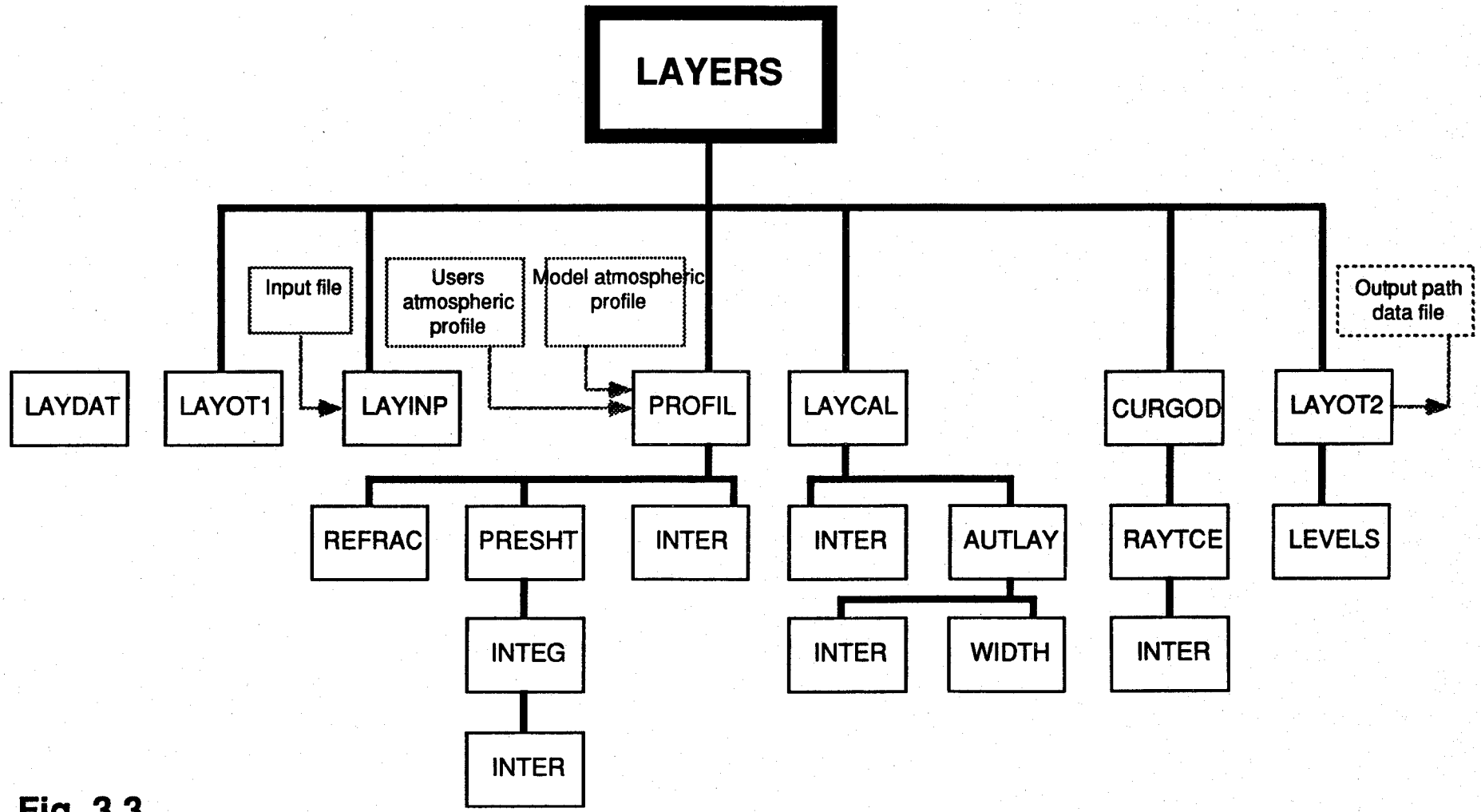


Fig. 3.3

Program structure for the LAYERS subroutines

Table 3.1 Program LAYERS reference input file

layers_input.ref


```
!           ***********************************************
!           *                                             *
!           *            PROGRAM LAYERS: INPUT FILE       *
!           *            --------------------------       *
!           *  GENLN2 PATH PRE-PROCESSING PROGRAM. PERFORMS *
!           *  ATMOSPHERIC LAYERING AND CALCULATES CURTIS   *
!           *  --GODSON ABSORBER WEIGHTED MEAN PATH         *
!           *  PARAMETERS. OUTPUT PATH FILE IS IN THE FORMAT *
!           *  REQUIRED FOR DIRECT INPUT TO GENLN2.         *
!           *  VERSION 3.0: D.P. EDWARDS 01/08/90           *
!           *                                             *
!           ***********************************************
!                                                   INPUT PARAMETER NAME
!-----------------------------------------------------------------------
!..TITLE INFORMATION FOR THIS LAYERS RUN (*TITLES) [MANDATORY]
*TITLES
!
!  1A. Title of this LAYERS run (80 characters max):                TITLEP
TITLEP
!!!!!!!! End of section !!!!!!!
!
!ONE and ONLY ONE of the following *USEPRO or *MODPRO must be supplied.
!
!-----------------------------------------------------------------------
!..USER PROFILE (*USEPRO) [MANDATORY if *MODPRO is not supplied]
*USEPRO
!
!  1A. Filename of user's profile data set (80 characters max):     FNPROF
FNPROF
!
!  2A. Filename of model profile data set to be used in conjunction
!      with user's profile for minor gas number densities etc
!      (80 characters max):                                         FNAFGL
FNAFGL
!
!  3A. Number of model profile to be used :                          MONO
!      1. Tropical            2. Midlatitude Summer
!      3. Midlatitude Winter  4. Subarctic Summer
!      5. Subarctic Winter    6. U.S. Standard
MONO
!
!  4A. Logical specifier for supplementing the user's gas
!      number density profiles from the model profile if
!      the former fall to zero at the user's profile levels :        WADD
!  4B. logical specifier for supplementing the user's profile
!      levels with model profile levels at higher altitude :        TOPADD
WADD,  TOPADD
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------
!..MODEL PROFILE (*MODPRO) [MANDATORY if *USEPRO is not supplied]
*MODPRO
!
!  1A. Filename of model profile data set to be used (80 characters max): FNAFGL
FNAFGL
!  2A. Number of model profile to be used :                          MONO
!      1. Tropical            2. Midlatiude Summer
!      3. Midlatitude Winter  4. Subarctic Summer
!      5. Subarctic Winter    6. U.S. Standard
MONO
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------
!..INTEGRATION PARAMETERS (*SUBLAY) [MANDATORY]
*SUBLAY
!
!  1A. Integration sub-layer accuracy :                                NP
!  1B. Refraction switch :                                           LREF
NP,   LREF
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------
!..FREQUENCY PARAMETERS (*FREQCY) [MANDATORY]
*FREQCY
!
!  1.A Lower wavenumber bound of proposed GENLN2 calculation :         V1
!  1.B Upper wavenumber bound of proposed GENLN2 calculation :         V2
V1, V2
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------
!..PRINT SWITCH (*LEVELS) [NOT MANDATORY]
*LEVELS
!
!  This section sets a logical flag that causes extra data about
!  the level height structure to be output. This might be used
!  later in the input to a weighting function calculation.
!!!!!!!! End of section !!!!!!!
!
!ONE AND ONLY ONE of *USELAY or *DEFLAY must be supplied.
!
!-----------------------------------------------------------------------
!..USER SUPPLIED LAYERS (*USELAY) [MANDATORY if *DEFLAY are not supplied]
*USELAY
!
!  1.A Layer boundaries at height ('H') or pressure ('P') levels:     COOR
!  1.B Number of layers for calculation :                            NOLAY
!  1.C Number of different path gases in each layer :                NOGAS
COOR, NOLAY, NOGAS
!
!  For each different layer path gas (IG=1,NOGAS) 1 input record
!  2.A Line file no to be used in output file for paths of this gas :  IFILE(IG)
!  2.B Molecular ID of gas :                                          LISTG(IG)
!  2.C Isotope ID of gas :                                            LISTI(IG)
!  2.D Line shape character string (8 Char.) to be used in
!      output file for paths of this gas :                           SHAPE(IG)
!  2.E Continuum character string specifier 'CON     ' or 'NOCON'
!      to be used in output file for paths of this gas :              CNTM(IG)
!  2.F Layer number to be used in defining Snell's Law
!      constant= n(r)*r*sin(theta) for paths of this gas :           MLANG(IG)
!  2.G Ray initial zenith angle (theta) for layer MLANG(IG)  :      THETAL(IG)
IFILE(1), LISTG(1), LISTI(1), SHAPE(1), CNTM(1), MLANG(1), THETAL(1)
IFILE(2), LISTG(2), LISTI(2), SHAPE(2), CNTM(2), MLANG(2), THETAL(2)
                          |
                          |
IFILE(NOGAS),LISTG(NOGAS), LISTI(NOGAS), SHAPE(NOGAS),CNTM(NOGAS),
MLANG(NOGAS),THETAL(NOGAS)
!
!  For each layer (ILAY=1,NOLAY) 1 input record
!  3.A Layer number :                                                  ILAY
!  3.B Layer lower boundary (km if COOR='H' or mb if COOR='P') :     XLL(ILAY)
!  3.C Layer upper boundary (km if COOR='H' or mb if COOR='P') :     XLU(ILAY)
1       XLL(1)    XLU(1)
2       XLL(2)    XLU(2)
        |
        |
NOLAY  XLL(NOLAY)    XLU(NOLAY)
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------
!..AUTOMATIC LAYERING (*DEFLAY)
!  [MANDATORY if and only if *USEPTH, *USELAY, and *GASLAY are not supplied]
```

Table 3.1 Program LAYERS reference input file

layers_input.ref


```
*DEFLAY
!
!  Default layering controls:
!  1.A Max variation factor for average Voigt half width across a layer.
!      This value should lie between 1.0 and 2.0:                          WDIF
!  1.B Max temperature difference (K) across a layer at
!      the bottom of the atmosphere :                                      TDIFB
!  1.C Max temperature difference (K) across a layer at
!      the top of the atmosphere :                                         TDIFT
WDIF, TDIFB, TDIFT
!
!  2.A Atmosphere boundaries at height ('H') or pressure ('P') levels:      COOR
!  2.B Number of different path gases in each layer :                      NOGAS
COOR, NOGAS
!
!  For each different layer path gas (IG=1,NOGAS) 1 input record
!  3.A Line file no to be used in output file for paths of this gas :  IFILE(IG)
!  3.B Molecular ID of gas :                                           LISTG(IG)
!  3.C Isotope ID of gas :                                             LISTI(IG)
!  3.D Line shape character string (8 Char.) to be used in
!      output file for paths of this gas :                             SHAPE(IG)
!  3.E Continuum character string specifier 'CON     ' or 'NOCON'
!      to be used in output file for paths of this gas :                CNTM(IG)
IFILE(1), LISTG(1), LISTI(1), SHAPE(1), CNTM(1)
IFILE(2), LISTG(2), LISTI(2), SHAPE(2), CNTM(2)
                          |
                          |
IFILE(NOGAS),LISTG(NOGAS), LISTI(NOGAS), SHAPE(NOGAS),CNTM(NOGAS)
!
!  4.A Atmosphere lower boundary (km if COOR='H' or mb if COOR='P') :       ALL
!  4.B Atmosphere upper boundary (km if COOR='H' or mb if COOR='P') :       ALU
!  4.C Ray initial zenith angle (theta_0) at bottom of atmosphere :      THETAA
ALL, ALU, THETAA
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..END OF LAYERS INPUT (*ENDINP) [MANDATORY]
*ENDINP
!!!!!!!! End of section !!!!!!!
```

Table 3.2 Example of user profile data arrangement

Profile


```
!*****************************************************************
!  NORTHERN LATITUDES (+30deg) SPRING ATMOSPHERIC PROFILE
!*****************************************************************
! Profile records:
! Altitude (km), Pressure (mb), Temperature (K), Total Density (molecules/cm3)
! Gas mixing ratios for listed gases (ppmv)
!
'H'      92        8     ! 1st rec: H or P, # of levels, # of gas profiles
 1 3 4 5 6 8 10 12       ! 2nd rec: gas ID's, H2O,O3,N2O,CO,CH4,NO,NO2,HNO3
30.0     9.5             ! 3rd rec: latitude (deg), height (km) first level
   9.50 3.0701E+02 226.83 9.790E+18 5.045E+02 1.985E-01 3.072E-01 3.514E-02
                                    1.797E+00 6.553E-06 5.091E-04 1.739E-04
  10.50 2.6344E+02 219.93 8.670E+18 1.743E+02 1.989E-01 3.074E-01 3.601E-02
                                    1.783E+00 2.093E-05 3.425E-04 2.050E-04
  11.50 2.2494E+02 213.29 7.640E+18 6.019E+01 1.993E-01 3.076E-01 3.691E-02
                                    1.768E+00 6.685E-05 2.304E-04 2.418E-04
  12.50 1.9150E+02 207.52 6.680E+18 2.079E+01 1.997E-01 3.078E-01 3.783E-02
                                    1.754E+00 7.698E-05 1.550E-04 2.850E-04
  13.50 1.6212E+02 203.20 5.780E+18 7.181E+00 2.001E-01 3.083E-01 3.798E-02
                                    1.740E+00 7.834E-05 1.269E-04 3.361E-04
  14.50 1.3679E+02 204.05 4.870E+18 5.806E+00 2.253E-01 3.076E-01 3.746E-02
                                    1.726E+00 7.461E-05 1.279E-04 3.963E-04
  15.50 1.1652E+02 204.76 4.110E+18 3.932E+00 3.046E-01 3.037E-01 3.532E-02
                                    1.654E+00 7.836E-05 1.502E-04 5.051E-04
  16.50 9.8488E+01 205.51 3.470E+18 3.229E+00 5.164E-01 2.954E-01 3.080E-02
                                    1.598E+00 9.355E-05 1.952E-04 6.912E-04
  17.50 8.3492E+01 207.16 2.920E+18 3.131E+00 9.546E-01 2.826E-01 2.424E-02
                                    1.545E+00 1.164E-04 2.795E-04 1.066E-03
  18.50 7.0927E+01 207.95 2.470E+18 3.481E+00 1.514E+00 2.655E-01 1.776E-02
                                    1.471E+00 1.366E-04 4.165E-04 1.657E-03
  19.50 6.0288E+01 209.90 2.080E+18 3.832E+00 2.090E+00 2.445E-01 1.328E-02
                                    1.378E+00 1.492E-04 5.956E-04 2.473E-03
  20.50 5.1372E+01 212.46 1.750E+18 4.118E+00 2.763E+00 2.223E-01 1.091E-02
                                    1.288E+00 1.701E-04 8.297E-04 3.289E-03
  21.50 4.3772E+01 214.31 1.480E+18 4.259E+00 3.558E+00 2.016E-01 9.964E-03
                                    1.214E+00 2.212E-04 1.154E-03 3.954E-03
  22.50 3.7389E+01 214.94 1.260E+18 4.457E+00 4.397E+00 1.818E-01 9.789E-03
                                    1.157E+00 3.097E-04 1.537E-03 4.503E-03
  23.50 3.2019E+01 218.49 1.060E+18 4.679E+00 5.340E+00 1.615E-01 9.953E-03
                                    1.101E+00 4.246E-04 1.976E-03 4.806E-03
  24.50 2.7358E+01 219.74 9.030E+17 4.746E+00 6.182E+00 1.402E-01 1.019E-02
                                    1.033E+00 5.846E-04 2.599E-03 4.907E-03
  25.50 2.3507E+01 221.91 7.670E+17 4.813E+00 7.036E+00 1.164E-01 1.047E-02
                                    9.538E-01 8.437E-04 3.424E-03 4.824E-03
  26.50 2.0164E+01 224.28 6.520E+17 4.736E+00 7.593E+00 9.112E-02 1.097E-02
                                    8.768E-01 1.187E-03 4.244E-03 4.624E-03
  27.50 1.7327E+01 226.75 5.550E+17 4.944E+00 8.081E+00 7.021E-02 1.183E-02
                                    8.160E-01 1.558E-03 5.017E-03 4.351E-03
  28.50 1.4996E+01 229.90 4.720E+17 5.165E+00 8.578E+00 5.751E-02 1.297E-02
                                    7.776E-01 2.011E-03 5.911E-03 4.025E-03
  29.50 1.2970E+01 231.39 4.050E+17 5.315E+00 8.959E+00 5.163E-02 1.422E-02
                                    7.613E-01 2.583E-03 6.836E-03 3.667E-03
  30.50 1.1146E+01 232.77 3.480E+17 5.572E+00 9.203E+00 4.921E-02 1.547E-02
                                    7.616E-01 3.130E-03 7.487E-03 3.277E-03
  etc.
```

Table 3.3 Listing of the PARRAY parameter file

PARRAY


```
C-----------------------------------------------------------------------
C*** INCLUDE FILE: PARAMETER LIST DEFINING MAXIMUM ARRAY DIMENSIONS. ***
C-----------------------------------------------------------------------
C***** PROGRAM LAYERS: ARRAY DIMENSIONS: *****
C  MXPRO - MAX NO. OF PROFILE DATA POINTS
C  MXMOL - HIGHEST MOLECULAR ID IN USE                              [63]
C  MXPTH - MAX NO. OF PATHS TO BE CALCULATED
C
      PARAMETER (MXPRO=100,MXMOL=63,MXPTH=100)
C-----------------------------------------------------------------------
C***** PROGRAM GENLN2: TRANSMISSION ARRAY DIMENSIONS: *****
C  MXFIL - MAX NO. OF LINE DATA OR XSEC DATA FILES TO BE READ
C  MXISO - HIGHEST MOLECULAR ISOTOPE ID IN USE                       [8]
C  MXGAS - MAX NO. OF GASES TO BE READ FROM ANY LINE OR XSEC DATA SET
C  MXPMX - MAX NO. OF MIXED PATHS TO BE CALCULATED
C  MXINT - MAX NO. OF WAVENUMBER INTERVALS + 1
C  MXDIV - MAX NO. OF WAVENUMBER INTERVAL DIVISIONS + 1
C  MXLIN - MAX NO. OF LINES STORED IN CYCLIC BUFFER AT ANY TIME
C  MXXPT - MAX NO. OF XSEC POINTS PER TEMP FOR ANY MOLECULE      [12808]
C  MXTEM - MAX NO. OF XSEC TEMPERATURE SETS PER MOLECULE             [6]
C
      PARAMETER (MXFIL=2,MXISO=8,MXGAS=5,MXPMX=50,MXINT=201,
     + MXDIV=4001,MXLIN=4000,MXXPT=12808,MXTEM=6)
C--- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- ---
C***** PROGRAM GENLN2: RADIANCE ARRAY DIMENSIONS: *****
C  THESE CAN ALL BE SET TO 1 TO SAVE SPACE IF A TRANSMISSION ONLY
C  CALCULATION IS PERFORMED.
C  MXLAY - MAX NO. OF LAYERS USED TO DESCRIBE RADIATING ATMOSPHERE
C  MXATM - MAX NO. OF RADIATING ATMOSPHERES TO BE CONSIDERED
C  MXIRD = MXINT
C  MXDRD = MXDIV
C
      PARAMETER (MXLAY=50,MXATM=3,MXIRD=201,MXDRD=4001)
C--- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- --- ---
C  MXPDM - MAX VALUE OF MXPTH, MXPMX OR MXLAY
C
      PARAMETER (MXPDM=100)
C-----------------------------------------------------------------------
C***** POST-PROCESSING PROGRAMS: ARRAY DIMENSIONS: *****
C  MXCUR - MAX NO. OF CURVES FOR GRAPHICS
C  MXPTS - MAX NO. OF PLOTTING POINTS
C  MXRES - MAX NO. OF EXTERNAL SPECTRA FOR PLOTTING
C  MXRPT - MAX NO. OF DATA POINTS PER EXTERNAL SPECTRA
C
      PARAMETER (MXCUR=4,MXPTS=32768,MXRES=1,MXRPT=150)
C-----------------------------------------------------------------------
```

4. THE LINE-BY-LINE CALCULATION: PROGRAM GENLN2

4.1 Overview of the Program GENLN2

The GENLN2 program performs the line-by-line calculations. The basic input to the program are the line file produced by the HITLIN program and a set of homogeneous gas paths each defined by a gas amount, temperature and pressure. For atmospheric radiative transfer problems, the path data is obtained as the output of the LAYERS program. For the simulation of a laboratory experiment the path will be defined by the conditions within the gas cell. The input file also specifies how the optical depths of the various paths, once calculated, are to be combined to form mixed path transmittances and defines the radiance calculations. The basic stages of the line-by-line calculation are described below.

4.2 Spectral Modelling

The monochromatic absorption coefficient $k(\nu)$ in units of $1/(molecules.cm^{-2})$, at wave number ν $[cm^{-1}]$, is calculated for each spectral line i using the line parameters obtained from the HITLIN spectral line file. In the atmosphere, a spectral line is collision and Doppler broadened about the transition wavenumber ν_i, the spread being represented by the normalized line shape function $g(\nu, \nu_i)$ in $1/cm^{-1}$ such that

$$k(\nu) \;=\; S_i \; g(\nu, \nu_i), \tag{4.1}$$

where S_i, in $cm^{-1}/(molecules.cm^{-2})$, is the line strength adjusted for the local gas temperature. The line strengths and widths are read from the line data files at a standard temperature T_{ref} of 296 K and pressure p_{ref} of 1 atm, and must be adjusted to the path pressure p and temperature T. The following expression is used to calculate the line strength $S(T)_i$ from the strength $S(T_{ref})_i$ read from the line data file

$$\frac{S(T)_i}{S(T_{ref})_i} = \frac{Q(T_{ref})}{Q(T)} \; \frac{\exp(-\mathbf{hc}E_{L_i}/\mathbf{k}T)}{\exp(-\mathbf{hc}E_{L_i}/\mathbf{k}T_{ref})} \; \frac{[1-\exp(-\mathbf{hc}\nu_i/\mathbf{k}T)]}{[1-\exp(-\mathbf{hc}\nu_i/\mathbf{k}T_{ref})]}. \tag{4.2}$$

Here $Q(T)$ is the total internal partition function, E_L the energy of the lower state of the transition, $\mathbf{c}$ the speed of light, $\mathbf{h}$ the Planck constant, and $\mathbf{k}$ the Boltzmann constant. The ratio of total internal partition functions is calculated using the parameterization of *Gamache et al.* (1990). This is an improvement over the usual classical approximation for the independent temperature variation of the rotational and vibrational components of the partition function. The second term on the right in Eqn.(4.2) accounts for the ratio of Boltzmann populations, and the third for the effect of stimulated emission. It should be noted that the strengths as they appear on the HITRAN line data base are weighted for the natural abundance of the particular isotope in the terrestrial atmosphere. The line parameters may be used in calculations where different isotope abundances apply. In this case the line strength for a given isotope should be divided by the terrestrial fractional abundance and scaled according to the new fractional abundance.

The collision broadened line half width $\alpha_L(p,T)$ in cm^{-1} at a pressure p, partial pressure p_s, and temperature T is calculated as

$$\alpha_L(p,T)_i = \left(\frac{T_{ref}}{T}\right)^m \left(\alpha_{La}(p_{ref},T_{ref})_i \, \frac{(p-p_s)}{p_{ref}} + \alpha_{Ls}(p_{ref},T_{ref})_i \, \frac{p_s}{p_{ref}}\right), \tag{4.3}$$

where m is the positive coefficient of temperature dependence of the air-broadened half width (in the absence of other data, this coefficient is assumed the same for self-broadening), α_{La} is the air-broadened half width, and α_{Ls} the self-broadened half width.

The 1991 HITRAN data base includes some self-broadened half width data, but this is not complete for all molecules or all bands of a given molecule. If the data is absent, the self-broadened half width is set equal to the air-broadened half width, with the exception of H_2O where $\alpha_{Ls} = 5 \times \alpha_{La}$ (*Burch*, 1982). The user can modify this treatment by examining the code in subroutine PTHADJ.

4.3 Line Shape Modelling

Considerable attention has been given to line shape modelling in GENLN2. In the lower atmosphere pressure broadening of spectral lines is the dominant broadening process. This arises as a result of collisions between molecules producing a deformation of the molecular energy levels. This is most simply represented by the Lorentz line shape (*Goody and Yung*, 1989)

$$g_L(\nu, \nu_i) = \frac{1}{\pi} \frac{\alpha_{L_i}}{\alpha_{L_i}^2 + (\nu - \nu_i)^2}. \tag{4.4}$$

The Lorentz line shape agrees well with infrared measurements within a few wavenumbers of the centers of absorbing lines. Other theoretical line shape formulations have also been developed for the treatment of collision broadened lines. Each is derived with a different set of assumptions to describe the mechanism of the collisional process. GENLN2 has provision for calculating the *Van Vleck and Huber* (1977) line shape extended by *Clough et al.* (1980). This is applicable to absorption over the infrared and microwave regions,

$$g_{VVH}(\nu, \nu_i) = \frac{\nu}{\nu_i} \frac{\tanh(\mathrm{hc}\nu/2\mathrm{k}T)}{\tanh(\mathrm{hc}\nu_i/2\mathrm{k}T)} \left[g_L(\nu, \nu_i) + g_L(-\nu, \nu_i) \right]. \tag{4.5}$$

At high altitudes where the pressure is low, Doppler broadening of the spectral lines must be taken into account. This is a result of the velocity distribution of absorbing molecules relative to an observer. The normalized line shape is given by

$$g_D(\nu, \nu_i) = \frac{1}{\alpha_{D_i}\sqrt{\pi}} \exp\left(\frac{-\ln 2\ (\nu - \nu_i)^2}{\alpha_{D_i}^2} \right) \tag{4.6}$$

where α_D is the Doppler half width,

$$\alpha_{D_i} = \nu_i \left(\frac{2 \ln 2\ \mathrm{k}T}{mc^2} \right)^{\frac{1}{2}}. \tag{4.7}$$

The height at which Lorentz and Doppler broadening become comparable is dependent on the molecular mass m of the radiating molecule and the wavenumber ν_i of the transition. Because this height may be as low as the upper troposphere and since an atmospheric transmittance problem may extend from low to high altitude, it is in general important to consider the combined effect of Lorentz and Doppler broadening. For the 4.3 μm band of CO_2 the two broadening mechanisms become comparable at an altitude of about 27 km.

The Voigt profile (*Armstrong*, 1967) is appropriate to most cases of atmospheric transmittance. It may be regarded as a convolution of the Lorentz and Doppler line shapes and approximates to each in the appropriate limit. The normalized line shape is given by

$$g_V(\nu, \nu_i) = g_{0_i}\ K(x_i, y_i), \tag{4.8}$$

where

$$g_{0_i} = \frac{1}{\alpha_{D_i}} \left(\frac{\ln 2}{\pi} \right)^{\frac{1}{2}}; \qquad K(x_i, y_i) = \frac{y_i}{\pi} \int_{-\infty}^{+\infty} \frac{e^{-t^2}}{y_i^2 + (x_i - t)^2} dt$$

$$y_i = \frac{\alpha_{L_i}}{\alpha_{D_i}}(\ln 2)^{\frac{1}{2}}; \qquad x_i = \frac{(\nu - \nu_i)}{\alpha_{D_i}}(\ln 2)^{\frac{1}{2}}.$$

$K(x, y)$ is known as the Voigt function and is the real part of the complex probability function

$$w(z_i) = e^{-z_i^2}\left(1 + \frac{2}{\sqrt{\pi}}\int_0^{z_i} e^{t^2}\, dt\right), \tag{4.9}$$

where $z_i = x_i + \mathrm{i}y_i$. Unfortunately, the Voigt function has no simple analytical solution and must be evaluated numerically. The usual approach is to divide the x, y plane into several regions and use appropriate functional expansions of the integral in each so as to optimize the combination of accuracy and speed of computation.

Comparisons of line-by-line calculations with measurements taken by high spectral resolution instruments have shown the importance of the finer details of line shape. For some gases the simple Voigt line shape is inadequate. Effects such as line coupling or mixing, non-Lorentzian line wing effects and continuum absorption must be considered.

Line coupling occurs when collisions between a radiating molecule and broadening gas molecules cause the transfer of population between rotational-vibrational molecular states and a redistribution of spectral intensity within a band. At atmospheric pressures this can easily occur in a Q-branch where the spacing between adjacent rotational levels is less than several $\mathbf{k}T$, the most apparent effect being a reduction in the absorption coefficient in the wings of the branch. The effect is also observed in atmospheric P- and R-branches. This may be very important for the strong CO_2 Q-branches used by satellite instruments for atmospheric temperature sounding (*Edwards and Strow*, 1991). Using the theory of *Rosenkranz* (1975) the normalized line shape function is

$$g(\nu, \nu_i) \;=\; \frac{1}{\pi}\frac{\alpha_{L_i} \;+\; pY_i(\nu - \nu_i)}{\alpha_{L_i}^2 \;+\; (\nu - \nu_i)^2}, \tag{4.10}$$

where Y_i is the first-order coupling coefficient

$$Y_i = 2\sum_{k \neq i} \frac{d_k}{d_i}\frac{W_{ki}}{\nu_i - \nu_k}. \tag{4.11}$$

Here d_k and d_i are dipole matrix elements for lines k and i respectively and W_{ki} is the relaxation matrix element for coupling between line i and line k. The W_{ki} elements are obtained using a temperature dependent energy-gap scaling law (*Strow and Gentry*, 1986). For atmospheric radiative transfer applications this line shape must be convolved with the Doppler line profile. This gives

$$g(\nu, \nu_i) \;=\; g_{0_i}\big(\Re[w(z_i)] + pY_i \;\; \Im[w(z_i)]\big). \tag{4.12}$$

The first term of Eqn.(4.12) is the usual Voigt line shape, the second accounts for line coupling. The complex probability function and therefore the Voigt function are calculated in GENLN2 using the algorithm of *Humlicek* (1982).

The value of Y at temperature T in $[K]$ is parameterized as

$$\begin{aligned} Y_i = {} & (p - p_s)[A_{a_i} + B_{a_i}(T - 200) + C_{a_i}(T - 200)^2 + D_{a_i}(T - 200)^3] \\ & + p_s[A_{s_i} + B_{s_i}(T - 200) + C_{s_i}(T - 200)^2 + D_{s_i}(T - 200)^3] \end{aligned}, \tag{4.13}$$

where the parameters with the subscript a account for air-broadening, those with subscript s for self-broadening. This description of line coupling has been incorporated into the GENLN2 model. The parameters A, B, C, and D are stored in block data subroutine LINMIX for the CO_2 Q-branches at 617, 667, 720, 740, and 791 cm^{-1}. The Y coefficient is calculated at the same time that line strength and half width are adjusted for the temperature and pressure of the atmospheric path under consideration. Y is then carried in the code as an extra line parameter until the line profile is calculated according to Eqn.(4.12).

The sub-Lorentzian nature of the far wings of CO_2 lines is well known (*Cousin et al.*, 1985, and references therein). Usually, the line shape function $g(\nu, \nu_i)$ based on the impact theory is multiplied by a corrective factor χ to give an empirical line shape

$$g(\nu, \nu_i)^{empirical} = g(\nu, \nu_i)\ \chi(\nu, \nu_i). \tag{4.14}$$

The χ-factor is a correction to account for the finite duration of collision between the broadening gas and the radiating molecule. This is assumed instantaneous in the impact approximation which forms the basis of most collision broadened line shape theories. It also includes the effect of line coupling far from band center since the χ-factor essentially represents the difference between measurement and Lorentzian line wing theory. The factor usually takes the form of an exponential with adjustable parameters and decays from unity at line center. These parameters have traditionally been chosen by fitting the calculated absorption to the measured absorption in the region above the CO_2 ν_3 band head at 4.3 μm. The χ-factors calculated in this region are often used in CO_2 line shapes at other vibrational bands. The user should be aware that the component of the factor due to line coupling will then be in error as it is dependent on the symmetry of the vibrational levels connected by the transition through the number of available final rotational states. This is not usually a problem as the exponential part of the χ-factor due to duration of collision effects quickly dominates the contribution due to coupling. *Birnbaum* (1979) suggested a χ-factor comprising the product of a decaying exponential to account for the finite duration of collisions alone and a constant term for line coupling. The exponential term should be band independent while the constant coupling term will not. This is discussed further in *Edwards and Strow* (1991).

GENLN2 includes a CO_2 line shape option that includes the effect of line coupling and sub-Lorentzian line wings. If data is available, line coupling is included explicitly according to Eqn.(4.12) out to an arbitrary 10 cm^{-1} from line center. The line wings at greater distances from line center are modified by the temperature dependent χ-factor of *Cousin et al.* (1985). If line coupling data is not available then this sub-Lorentzian line shape is used everywhere.

4.4 Molecular Cross-Section Data

High resolution cross-section data are used to calculate absorption by molecules for which line data is not available. These molecules and the molecular ID's assigned to them are listed in Table 2.1. The data sets currently used are temperature dependent cross-sections for the CFCs (*McDaniel et al.*, 1991), N_2O_5 (*Cantrell et al.*, 1988), $ClONO_2$ (*Ballard et al.*, 1988) and the room temperature sets acquired at the University of Denver (*Massie et al.*, 1985). The temperature dependent data are a significant improvement over room temperature data and allow greater confidence in the results. When only room temperature data are available, the cross-section is scaled by the ratio of the total internal partition function evaluated at 296 K to that evaluated at the path temperature. Cross-sectional data is very important for modelling many of the heavy molecules of interest in atmospheric studies and although the method is only approximate, the errors are considerably less than if the absorption contribution of these molecules is neglected.

4.5 The Line-By-Line Calculation

The line-by-line calculation involves calculating transmittances over the spectral range of interest in wavenumber space for each gas in several atmospheric layers. The simplest procedure is to choose a wavenumber grid fine enough that the narrowest line is adequately sampled, typically 0.0005 cm^{-1}. Then for each line i of path gas j taken in turn the monochromatic absorption is calculated at each grid point over the whole wavenumber range. The absorption coefficient at a wavenumber ν can be written as the sum over the absorption contributions from all lines i in the spectral range,

$$k(\nu)_j = \sum_{all\ lines\ i} S_{ij}\, g(\nu, \nu_i)_j. \tag{4.15}$$

Here S_{ij} is the strength of line i adjusted to the conditions of path j and $g(\nu, \nu_i)_j$ is the line shape function for line i. The total transmittance of a mixed path comprising J single gas paths over several layers of the atmosphere is then

$$\tau(\nu) = \exp\left(-\sum_{j=1}^{J} k(\nu)_j\, u_j\right), \tag{4.16}$$

where the path gas amount u_j per cross-sectional area in $molecules.cm^{-2}$ is defined in Eqn.(3.2). Eqn.(4.16) is the approximation used to calculate the integral of Eqn.(1.3). In GENLN2 the line strength is scaled by the Avagadro number (6.022×10^{26}) in program HITLIN to avoid underflow problems with very weak lines. To compensate for this, the unit actually used by the code for gas amount is $kg.moles.cm^{-2}$.

To calculate the absorption coefficient for every line at every wavenumber grid point is prohibitive for most applications and represents an excessive amount of computer time and storage. Most algorithms that speed up the computation work on the basis that a wider wavenumber grid may reasonably be used in the wings of lines whilst a fine grid is required over the line center where the line profile is changing rapidly. The calculation also only needs to be performed for lines of significant strength.

In GENLN2 the spectral calculation is fully specified by the user input. The wavenumber range is first divided into a number of wide mesh intervals, Fig.4.1, which may be of constant or variable spacing. The line-by-line multi-path calculation proceeds in two stages. For each gas path a 'wide-pass' is first made over the total spectral range. For each wide mesh in turn, the absorption due to the wings of lines whose centers fall into the range FEXC to FWIND [cm^{-1}] from the wide mesh boundaries are computed at the lower boundary, center, and upper boundary of the interval. The absorption contribution of the wings of lines whose centers are further than FWIND [cm^{-1}] from the wide mesh boundary are included by means of a pre-computed temperature dependent continuum described in the next section. The contribution of far line wings and of lines lying outside of the wavenumber range of interest is important, especially near strong absorption bands (*Fischer et al.*, 1988). When the absorption contributions from all far-off line wings have been considered, a quadratic interpolation between the three values at the wide mesh wavenumber points gives the total line wing absorption at intermediate points.

A 'fine-pass' is then made over a fine wavenumber grid obtained by sub-dividing the wide mesh interval into many smaller intervals. This absorption calculation is performed for close lines where the line shape may be changing very rapidly. All lines whose centers lie within FEXC [cm^{-1}] of the wide mesh boundaries are included. The number of fine grid points within each wide mesh interval defines the resolution of the calculation and is determined by the width of the narrowest line encountered.

The interpolated wide-pass absorptions at the fine grid wavenumber points are then added to the fine-pass absorptions at these same points. This gives the line absorption totals within each wide mesh interval.

GENLN2 includes a line selection so that the line-by-line calculation is not performed for extremely weak lines. The minimum line strength is determined as follows. An Elsasser distribution of lines (*Goody and Yung*, 1989) of half width 0.1 cm^{-1}, peak separation 0.01 cm^{-1} and constant strength S, is assumed to represent the extreme case of a tight absorption band of low optical depth. If for path j, the transmittance of such a line distribution is greater than 0.99999 then the lines are not considered significant. This condition implies a minimum value of $S_j u_j$ for the line to be used. The wide-pass stage of the calculation rejects lines for which $S_j u_j < 10^{-7}$ and the fine-pass stage rejects lines for which $S_j u_j < 10^{-8}$. These values are set in subroutines WIDEPS and FINEPS with the variable STMIN. To perform the calculation using all lines STMIN should be set to zero. The user should be aware that this condition for line rejection is only relevant for lower and middle terrestrial atmosphere studies and should be changed if GENLN2 is used for other applications.

Transmittances are required over the spectral range of interest for each single gas path in the several tens of atmospheric layers. To store the absorption coefficients for the whole spectrum for all paths would result in prohibitively large array sizes. GENLN2 performs a 'vertical' calculation in that the absorption coefficients are calculated for all paths in all layers but are only stored for each wide mesh interval before being written to output. Thus at any one time the monochromatic optical depths of all gas paths in all layers are known for one wide mesh interval.

4.6 Continuum Absorption

In addition to line-by-line absorption, the continuum absorption of certain molecules, in particular water vapor, must also be considered. This is especially important in remote sensing applications which utilize the infrared atmospheric windows around 4 μm and at 8–12 μm. The H_2O continuum is responsible for most of the absorption in these regions and the large seasonal and zonal variations in the H_2O mixing ratio in the troposphere can lead to a wide range of calculated attenuations.

The continuum absorption has sometimes been called "anomalous" absorption because it is not accounted for by line shapes based on simple collision broadening theory and having Lorentzian wings. It may be considered as making up the difference between the observed absorption and that resulting from a sum over all H_2O spectral lines in the atmospheric window regions that are located near to strong water bands. Thus its definition will depend on the reference line shape chosen, and this, along with the spectral region of interest, will determine if the continuum represents a "surplus" or "deficit" of absorption. The continuum formulation is therefore inextricably linked to the line shape description and the lack of formal agreement on definition has led to confusion and hindered comparison of different models (*Clough et al.*, 1989b).

Despite much effort, there is still no comprehensive theory to account for the continuum. It is essentially broadband, decreases rapidly with temperature and in the 8–12 μm window, is much stronger for pure water vapor where self-broadening effects are important than for air-broadened lines. Fig. 4.2 shows the continuum contribution to the total radiance for a zenith view at sea level in a tropical atmosphere. There have been two general theories for explaining the continuum; the far spectral line wing absorption by water vapor monomers, and the absorption by water vapor dimers (*Bignell*, 1970; *Gebbie*, 1982). The negative temperature dependence is suggested as possible evidence for the dimer theory (*Suck*, 1982; *Varanassi*, 1988) since dimer populations would be expected to decrease rapidly with

increasing temperature. However, spectral features of the dimer are not observed in the water vapor continuum (*Burch*, 1982), and the theory would require a strong dimer absorption band everywhere that the continuum is found. Measurements on saturated water vapor also suggest that dimer absorption is an of magnitude too small to account for the observations (*Hinderling et al.*, 1987).

Recent studies have concentrated on explaining the far wing contributions to the water vapor absorption and to understanding the intermolecular potential and duration of collision which determine absorption in this part of the line profile. Total line shapes that include empirically fitted parameters have been developed by a number of authors (Clough et al., 1980; *Thomas and Nordstrom*, 1985; *Rosenkranz*, 1985, 1987; *Ma and Tipping*, 1990), and these have met with some success in reproducing the continuum magnitude, frequency and quadratic pressure dependences, as well as the relative effectiveness of self-broadening compared to foreign-broadening. The strong negative temperature dependence remains a problem, although advances have been made recently with the work of Rosenkranz, extended by Ma and Tipping. This is able to produce a strong temperature dependence that is consistent with observations in the far-wing.

Laboratory studies of water vapor continuum absorption using a spectrometer are made difficult by the long paths required, and most (notably those of Burch) have been of necessity conducted at temperatures of 296 K or higher. Atmospheric temperatures are usually considerably lower, and due to the strong temperature dependence of continuum absorption a large degree of uncertainty exists if, as is usual, an exponential relation is used to extrapolate measurements above 296 K to lower temperatures. Measurements in the atmosphere are therefore very useful but few in number. A review of atmospheric and laboratory measurements is given by *Grant* (1990). For a more detailed discussion of continuum modelling see *Kilsby et al.* (1992).

The need for a continuum absorption parameterization that can be used in radiative transfer models has led to the semi-empirical approach being adopted. The model of *Clough et al.* (1980, 1989b) has been used in the Air Force Geophysics Laboratory codes FASCODE (*Clough et al.*, 1989a), LOWTRAN (*Kneizys et al.*, 1988), and is used in GENLN2. It describes the far line wings using the Van Vleck and Huber impact approximation line shape modified by an empirically determined factor to fit the calculated absorption to the experimental data of *Burch and Alt* (1984).

The continuum absorption coefficient $k_c(\nu)$ due to all lines i is defined by

$$k_c(\nu) \;=\; \nu \tanh\!\left(\frac{\mathrm{hc}\nu}{2\mathrm{k}T}\right) \sum_i \frac{S_i}{\nu_i \;\tanh(\mathrm{hc}\nu_i/2\mathrm{k}T)} \Big(g_c(\nu,\nu_i)\;\chi(\nu,\nu_i) \;+\; g_c(-\nu,\nu_i)\;\chi(-\nu,\nu_i)\Big), \tag{4.17}$$

where

$$g_c(\pm\nu,\nu_i) \;=\; \frac{1}{\pi}\,\frac{\alpha_{L_i}}{\alpha_{L_i}^2 \;+\; (\nu \pm \nu_i)^2} \qquad \text{for} \quad |\,(\nu \pm \nu_i)\,| \geq 25cm^{-1}, \tag{4.18}$$

and

$$g_c(\pm\nu,\nu_i) \;=\; \frac{1}{\pi}\,\frac{\alpha_{L_i}}{\alpha_{L_i}^2 \;+\; 25^2} \qquad \text{for} \quad |\,(\nu \pm \nu_i)\,| \leq 25cm^{-1}. \tag{4.19}$$

This description includes a constant continuum component over the line center region to avoid a discontinuity at 25 cm^{-1} from line center. This component must be remembered when performing the line-by-line calculation out to 25 cm^{-1} from line center so that it is not counted twice.

Eqn.(4.17) may be written

$$k_c(\nu) \;=\; \nu \tanh(\mathrm{hc}\nu/2\mathrm{k}T)\; C(\nu) \tag{4.20}$$

where $C(\nu)$ is the wavenumber dependent continuum parameter. For water vapor in the infrared, $\chi = 1$ within about 5 cm^{-1} of the line center. At greater distances up to about 500 cm^{-1} the line shape becomes super-Lorentzian. The χ factor is dependent on $(\nu - \nu_i)$ and approaches values as high as 10 for the self-broadened case. At greater distances still the line becomes sub-Lorentzian. Similar behavior is found in the air-broadened case though to a lesser extent, with $\chi > 1$ up to about 100 cm^{-1} from line center.

Applying this definition of the continuum, the total continuum contribution to the absorption coefficient $k_c(\nu)$ at some wavenumber ν can be written

$$k_c(\nu) = \nu \ \tanh(\mathrm{hc}\nu/2\mathrm{k}T) \left(\frac{T_{ref}}{T}\right) \left(\frac{p_s}{p_{ref}} C_s^0(\nu,T) + \frac{(p-p_s)}{p_{ref}} C_f^0(\nu,T)\right). \tag{4.21}$$

C_s^0 is the continuum absorption parameter for the self component and C_f^0 is the parameter for the foreign component, both have units of $1/(cm^{-1}.molecules.cm^{-2})$. C_s^0 and C_f^0 are defined at a reference pressure, and the temperature and pressure factors in Eqn.(4.21) take into account the density dependence of the self and foreign broadened line half widths. Values of C_s^0 are stored in the code at temperatures of 260 K and 296 K. The strong negative temperature dependence is obtained by exponentially extrapolating between these values at the required wavenumber. Due to a lack of measurements at lower temperatures, the 260 K data is an extrapolation of Burch's measurements at 296 K and 338 K and as such is a potential source of error. The temperature dependence of C_f has not been determined and room temperature values are used.

The line-by-line part of the GENLN2 calculation takes into account line wings up to 25 cm^{-1} from the line center. The pre-computed continua described here account for the absorption contribution of the line wings at greater separations.

In addition to H_2O, a CO_2 continuum is also included. This has been calculated using the GENLN2 CO_2 line shape. The continuum is stored in the code at temperatures of 230 K, 250 K and 296 K and the absorption at a particular path temperature is obtained by interpolation between these values at the required wavenumber.

The pressure broadened band of N_2 at 2350 cm^{-1} (*Clough et al.*, 1981) and that of O_2 at 1550 cm^{-1} (*Timofeyev and Tonkov*, 1978; *Rinsland et al.*, 1989) are also included as broad-band continuum contributions to the absorption. The same facility may be used to include other grey absorptions such as aerosols.

4.7 Transmittance Calculations

Having calculated the various components contributing to absorption at the fine grid wavenumber points for some path j, the total monochromatic absorption coefficient may be formed,

$$k(\nu)_j = k(\nu)_j^{line-wings} + k(\nu)_j^{near\ lines} + k(\nu)_j^{broadband}. \tag{4.22}$$

The broadband absorption includes the continuum and molecular cross-section contributions. The monochromatic optical depth of the path is given by the product of the absorption coefficient and the total path absorber amount, $k(\nu)_j u_j$. At this stage the optical depths of the various single gas paths may be combined to obtain multi-gas optical depths and optical depths over several layers according to the problem being addressed. This operation is performed in GENLN2 by a device called a mixing table, here represented by the matrix M. The elements $M_{m,j}$ specify the contribution that each path optical depth $k(\nu)_j u_j$ is to make in forming the mixed path optical depth $K(\nu)_m$ for some mixed path m. If there

are N_m mixed path absorptions to be formed from the N_p computed path absorptions the calculation takes the form,

$$\begin{pmatrix} K(\nu)_1 \\ K(\nu)_2 \\ \vdots \\ K(\nu)_{N_m} \end{pmatrix} = \begin{pmatrix} M_{1,1} & M_{1,2} & \dots & M_{1,N_p} \\ M_{2,1} & M_{2,2} & \dots & M_{2,N_p} \\ \vdots & \vdots & \ddots & \vdots \\ M_{N_m,1} & M_{N_m,2} & \dots & M_{N_m,N_p} \end{pmatrix} \begin{pmatrix} k(\nu)_1 u_1 \\ k(\nu)_2 u_2 \\ \vdots \\ k(\nu)_{N_p} u_{N_p} \end{pmatrix}. \tag{4.23}$$

This calculation is performed over each point of the fine wavenumber grid. The transmittance of each mixed path is then calculated according to

$$\tau(\nu)_m = \exp(-K(\nu)_m). \tag{4.24}$$

The mixing table is a versatile device which allows for economy of calculation of many atmospheric mixed paths. For example, slant path calculations through the atmosphere for a series of small angles may be simply performed by multiplying the vertical path absorptions by $\sec\theta$, where θ is the local zenith angle. Such a calculation does not take into account refraction effects but this is not found to be a serious source of error for values of θ less than about 60°. It represents a considerable economy of calculation when several slant path views for the same atmospheric profile are to be computed. The mixing table is also very useful for performing several transmittance calculations in parallel for slightly different atmospheric profiles. If the profiles have paths in common then the optical depths of these need only be computed once and combined with the path absorptions of other gases in the mixed paths as required. An application of this might be in determining the sensitivity of the atmospheric absorption to differing amounts of one particular gas, the mixing ratio profiles of the other gases remaining constant.

An example mixing table is shown in Fig.4.3 along with an illustration of the mixed paths it calculates. The table uses the set of 15 paths shown in the example of Fig.3.1. Mixed path 1 shows how the optical depths of several layers may be combined for a single gas. This mixed path may be used to find the transmittance of the atmosphere due to water vapor alone. Mixed paths 2–4 are for a calculation to investigate the attenuating effect of mixed gas absorption from different levels in the atmosphere. Mixed paths 5 and 6 represent a slant path calculation for a zenith angle of $\theta = 45°$. Mixed paths 7–11 calculate the total optical depth for each layer of the atmosphere. These mixed paths could be used to represent the layer in a GENLN2 radiance calculation in the way described in the next section. The example shown here is for a nadir viewing geometry. For a limb-viewing geometry the mixing table is used to combine path optical depths for different gases within a layer and between layers in the same manner.

4.8 Radiance Calculations

GENLN2 may be run in one of two modes, for transmittance calculations only or for transmittance and radiance. A typical nadir viewing problem in satellite remote sensing might be the calculation of radiance at some altitude z_{obs} above the Earth due to the combined effect of a radiating surface at z_s such as the land, sea or cloud top and the thermal emission of the atmosphere. In this case the radiative transfer equation from Eqn.(1.6) is

$$I(\nu, z_{obs}) = I(\nu, z_s)\, \tau(\nu, z_s, z_{obs}) + \int_{z_s}^{z_{obs}} \left[B(\nu, T(z))\, k(\nu, z) \rho_a(z)\, dz \right] \tau(\nu, z, z_{obs}), \tag{4.25}$$

where $I(\nu, z_s)$ is the intensity of radiation leaving the surface, ρ_a is the density of the absorbing gas and $B(\nu, T)$ is the Planck emission function at temperature T. In general $I(\nu, z_s)$ is given

by

$$I(\nu, z_s) = \epsilon\, B(\nu, T_s) + (1 - \epsilon) \Bigg(B(\nu, T_b)\, \tau(\nu, z_b, z_s) + \int_{z_b}^{z_s} \Big[B(\nu, T(z))\, k(\nu, z) \rho_a(z)\, dz \Big]\, \tau(\nu, z, z_s) \Bigg), \tag{4.26}$$

where ϵ is the emittance and T_s the temperature of the surface. The effective edge of the Earth's atmosphere is z_b, and T_b the temperature at this boundary. The first term of Eqn.(4.26) is the thermal emission of the surface. Assuming specular reflection, the second term represents the reflectance multiplied by the total radiation reaching the surface from the atmosphere. The latter is zero if the surface is a blackbody with $\epsilon = 1$. For a limb viewing case looking into deep space, the observed radiance will be due to atmospheric thermal emission alone and will be given by a term similar to Eqn.(4.25) with the first term set to zero and z_b substituted for z_s.

In the GENLN2 radiance calculation the atmosphere is considered sub-divided into a number of homogeneous layers. The total optical depth of each layer l is defined in the GENLN2 input from among the computed path optical depths, $k(\nu)_j u_j$, or mixed path optical depths, $K(\nu)_m$. Assuming that the layer is made up of J single gas paths, the total layer optical depth $\psi(\nu)_l$ will be given by a mixed path m for which

$$\psi(\nu)_l \equiv K(\nu)_m = \sum_{j=1}^{J} k(\nu)_j u_j, \tag{4.27}$$

and the layer transmittance is

$$\tau(\nu)_l = \exp(-\psi(\nu)_l). \tag{4.28}$$

Each layer also has an associated temperature T_l which is an absorption weighted mean of the path temperatures that constitute the layer. For a layer in local thermodynamic equilibrium this allows the layer thermal emission $E(\nu)_l$ to be defined from the integral in Eqn.(4.25) and Eqn.(3.2) as

$$\begin{aligned} E(\nu)_l &= B(\nu, T_l) \sum_{j=1}^{J} k(\nu)_j\, \rho_{a_j} \int_{z_{l_-}}^{z_{l_+}} \tau(\nu, z, z_{l_+})\, dz \\ &= B(\nu, T_l) \left(\frac{\phi(\nu)_l}{\psi(\nu)_l} \right) [1 - \tau(\nu)_l], \end{aligned} \tag{4.29}$$

where

$$\phi_l = \sum_{j=1}^{J} k(\nu)_j u_j. \tag{4.30}$$

The optical depth ratio $(\phi(\nu)_l / \psi(\nu)_l)$ is unity as it stands, but has been retained here to demonstrate how GENLN2 performs an emission calculation. It is often useful to know what component of the total radiance at some point in the atmosphere is due to the emission from one particular gas species. For example, it is necessary to know how much of the measured instrument signal in a CO_2 sounding channel is due to a contaminating O_3 signal. Consider a calculation to find the radiance due only to gas C when the atmosphere is composed of gases A, B, C, and D. Whatever the emission source, it will be attenuated according to the layer transmittance $\tau(\nu)_l$ which is defined by the layer optical depth ψ_l of all the gases A, B, C and D. The optical depth of gas C alone is then used to define the layer emission, i.e.

$\phi(\nu)_l = k(\nu)_C u_C$ only. For such a GENLN2 calculation, the user must define in each layer, a total optical depth $\psi(\nu)_l$ and the emission source optical depth $\phi(\nu)_l$, by choosing from among the previously calculated path and mixed path optical depths.

The radiance calculation then proceeds in two stages. First Eqn.(4.26) for the radiation leaving the surface is evaluated if it is defined by the problem. The radiance at the point of observation is then calculated using Eqn.(4.25). In both cases the same step-wise algorithm is used to calculate the radiance at the furthest boundary of the lth layer as

$$I(\nu)_l = I(\nu)_{l-1}\, \tau(\nu)_l \; + \; E(\nu)_l. \tag{4.31}$$

GENLN2 allows several radiance calculations to be performed at once. Each calculation is specified by the layer optical depths which define the radiating atmosphere and the boundary temperatures and emittances where appropriate.

4.9 Description of GENLN2 Subroutines

The GENLN2 program structure is shown in Fig.4.4.

GENLN2 - Main program. Management program for the calculation.

GENDAT - Block data subroutine. Initializes data for GENLN2 common blocks.

OUTDT1 - Subroutine. Initializes the formatted summary output data file and writes a header. The output file will be used for any error messages written during the input processing.

TIMER - SYSTEM SPECIFIC: Subroutine. This routine returns the system date and the CPU run time at call. It relies on system specific function calls. It is supplied in skeletal form and will require editing before it will perform its function.

INPUT - Subroutine. Main input routine to read the user's input data file which defines the GENLN2 task. The routine searches the input for the *KEYWORD entries and calls the relevant input subroutine to read the section.

TITLES - Subroutine. Reads the *TITLES title and output specification section of the main input file.

GASFIL - Subroutine. Reads the *GASFIL line data file information section of the main input file.

XSCFIL - Subroutine. Reads the *XSCFIL molecular cross-section information section of the main input file.

USEGRD - Subroutine. Reads the *USEGRD and *GRDFIL sections of the main input file. Opens and reads the user's data file defining the wavenumber boundaries of the wide mesh intervals.

DEFGRD - Subroutine. Reads the *DEFGRD section of the main input file and calculates the wavenumber boundaries of the wide mesh intervals.

RADIOM - Subroutine. Reads the *RADIOM section of the main input file. Opens and reads the user's data file containing wavenumber boundaries of the wide mesh intervals and the values of the radiometer filter response mask.

SPECTM - Subroutine. Reads the *SPECTM spectral calculation definition section of the main input file.

PTHFIL - Subroutine. Reads the *PTHFIL section of the main input file. Opens and reads the user's path data file from the output of program LAYERS.

PTHPAR - Subroutine. Reads the *PTHPAR path data section of the main input file.

MIXING - Subroutine. Reads the *MIXING and *MIXFIL sections of the main input file. Opens and reads the user's mixing table data file.

RADNCE - Subroutine. Reads the *RADNCE and *RADFIL section of the main input file. Opens and reads the user's radiance input data file.

OUTPUT - Subroutine. Reads the *OUTPUT output data specification section of the input file.

OUTDT2 - Subroutine. Writes a summary of the input file data just read to the formatted summary output data file.

WIDEPS - Subroutine. Performs the line-by-line wide-pass absorption calculation for absorption due to the line wings over all the wide mesh wavenumber intervals and for all paths. If the fine grid wavenumber interval is being chosen according to the minimum line width encountered, i.e. NDIV<0 in the *SPECTM section of the input file, then this minimum line width adjusted for path conditions is found and used to calculate the fine grid spacing in each wide mesh.

HITINI - Subroutine. Initializes the reading of the line data file(s) containing the line parameters (output of the HITLIN program).

HITRD - Subroutine. Reads the line data file and returns the line parameters of a wanted gas.

LINMIX - Block data. Contains the parameters for the line coupling calculation.

PTHADJ - Subroutine. According to the gas path conditions, this routine calculates the pressure and Doppler broadened widths, strength and line coupling coefficient from the parameters of the last line read from the line data file. If isotope abundances other than those of the terrestrial atmosphere are to be used, they should be set in this subroutine.

ISOTPE - Block data. Contains the HITRAN isotope masses and abundances.

QTFCT - Subroutine. Calculates the total internal partition function for the molecules included on the HITRAN data base given the given molecular species and the temperature.

QTIPS - Block data. Data for the calculation of total partition function. This is essentially the TIPS program of *Gamache et al.* (1990).

QTINT - Subroutine. Calculates the total internal partition function for gases other than the 32 included on the HITRAN data base, i.e. the heavy molecules for which only cross-section data are available.

QSHEV - Block data. Data for the calculation of the total internal partition function of the heavy molecules.

CONSUB - Subroutine. This routine calculates the absorption component over the line center that is included in the Clough et al. (1980, 1989) definition of the H_2O

continuum. This component is not then included in the GENLN2 line-by-line calculation when a continuum calculation is involved.

LORNTZ - Subroutine. Calculates the absorption assuming a Lorentz line profile over the wide mesh interval.

VOIGT - Subroutine. Calculates the absorption assuming a Voigt line profile over the wide mesh interval.

VOIVEC - Subroutine. Calculates the complex probability function using a vectorized version of the *Humlicek* (1982) routine.

NEWSHP - Subroutine. This is a skeleton routine which the user can modify for their own line shape function which is than calculated over the wide mesh interval.

VOICO2 - Subroutine. Calculates the absorption assuming a Voigt line profile modified for CO_2 sub-Lorentzian line wings and line coupling over the wide mesh interval.

VANHUB - Subroutine. Calculates the absorption assuming the modified Van Vleck and Huber line profile over the wide mesh interval.

DOPLER - Subroutine. Calculates the absorption assuming a Doppler line profile over the wide mesh interval.

CONTUM - Subroutine. Calculates the continuum absorption over all the wide mesh wavenumber intervals for specified paths.

CO2FT0 - Block data. CO_2 continuum coefficients at 296 K.

CO2FT1 - Block data. CO_2 continuum coefficients at 260 K.

CO2FT2 - Block data. CO_2 continuum coefficients at 230 K.

H2OST0 - Block data. H_2O self-density dependent continuum coefficients at 296 K.

H2OST1 - Block data. H_2O self-density dependent continuum coefficients at 260 K.

H2OFT0 - Block data. H_2O foreign-density dependent continuum coefficients at 296 K.

N2CT0 - Block data. N_2 collision induced continuum coefficients at 296 K.

O2CTT - Block data. O_2 collision induced continuum coefficients at 293 K, 253 K and 213 K.

OUTGR1 - Subroutine. Opens the unformatted output data file specified in the *OUTPUT section of the input file and writes a summary of the input file data.

WINGCO - Subroutine. Interpolates the wide-pass and continuum absorptions calculated at the three wavenumber points of the current wide mesh interval onto the fine grid of the interval for all paths.

XSECAB - Subroutine. Calculates the absorption by path and wide mesh interval for those heavy molecules whose absorption is represented by molecular cross-sections. This routine uses the cross-section absorption data file **xsec.dat**.

FINEPS - Subroutine. Performs the line-by-line fine-pass calculation of the absorption due to near lines at the fine grid wavenumber points of the current wide mesh interval and for all paths.

CYCRD - Subroutine. Manages the cyclic buffers of line parameters for lines that contribute to the fine-pass line-by-line absorption calculation over the fine grid wavenumber points in the current wide mesh interval.

BUFSWP - Subroutine. Stores the line parameters for the last line read in the current cyclic buffer range for a particular line data file before bringing into play the line parameters of the first useful line of the next line data file being used.

TRINTG - Subroutine. General purpose integration routine using the trapezium rule. Used to integrate the radiometer response function, path, mixed path, and layer transmittances and radiances over each wide mesh interval.

MIXPTH - Subroutine. Performs the mixed path absorption calculation for all mixed paths over the fine grid of the current wide mesh interval. Uses the mixing table and path absorptions already calculated. A path absorption weighted mean temperature is also calculated to represent the temperature of each mixed path.

OUTGR2 - Subroutine. Writes to the unformatted output data file the specified path and mixed path transmittances at the fine grid wavenumber points of the current wide mesh interval.

EMISSN - Subroutine. Performs the transmittance, emission and radiance calculation on the fine wavenumber grid for all layers of the current radiating atmosphere and wide mesh interval.

PLANCK - Subroutine. Calculates the Planck function at given temperature over the fine wavenumber grid for the current wide mesh interval.

OUTGR3 - Subroutine. Writes to the unformatted output data file the specified atmosphere and layer transmittances and radiances over the fine wavenumber grid for the current wide mesh interval.

OUTDT3 - Subroutine. Writes to the formatted output file the specified spectra binned and integrated over the current wide mesh interval.

OUTGR4 - Subroutine. Writes to the unformatted output file the specified spectra binned and integrated over the current wide mesh interval.

4.10 Description of the GENLN2 Input File

Input to GENLN2 is by means of a user supplied input file in the standard format described in Section 1.3. This is assigned to FORTRAN unit number 4 before execution commences. Table 4.1 gives details of the input file. The different *KEYWORD sections are described below.

***TITLES**

This section is mandatory.

(1A) TITLE (40 character string) is the title of the GENLN2 run. This is used as a header for the output files and should be descriptive.

(2A) AVER (logical) is a print switch to reduce the amount of output in the formatted

summary output file. If AVER is set to .TRUE. then the printing of the average spectral values binned over each wide mesh is suppressed and only the average value over the full passband range is printed. If AVER is set to .FALSE. then the full data is output.
(2B) MXER (logical) is also a print switch. If it is set to .TRUE. then the mixing table is not reproduced in the summary output file. Remember that mixing tables can get very large!

Next comes the input that will specify which transmittances and radiances are written to the formatted summary output data file as it is unlikely that all the possible GENLN2 output will be needed.
(3A) IDAT (integer) allows the path, mixed path or layer transmittance and radiance integrated spectra to be chosen. These three categories take the values IDAT= 1, 2, and 3 respectively.
(4A) IATM (integer) specifies the relevant atmosphere number (radiance calculation number) when IDAT= 3. For IDAT= 1 or 2 this is absent. Setting IATM< 0 results in spectra for all atmospheres being printed.
(4B) NP (integer) specifies the number of paths, mixed paths or layers to be printed. If NP< 0 then all are printed.
(5A) IOPDT (integer) gives the list of NP (if NP> 0) path, mixed path, or layer numbers to be printed. 5A is absent if NP< 0. The above input parameters are repeated as required, each time beginning at the value of IDAT.

In the output section here and in *OUTPUT which specifies the spectral output that will be written to the GENLN2 unformatted output file, a path or mixed path transmittance is the transmittance calculated over the specified path or mixed path. The layer transmittance calculated during the the radiating atmosphere calculation refers to the total transmittance from the initiating boundary of the atmosphere to the furthest boundary of the specified layer in the direction of radiation travel along the ray path. The radiance is also reported at this same layer boundary. Note that layers for a radiance calculation are numbered sequentially in the direction of radiation travel with the initiating surface of the radiating atmosphere forming the lower boundary of layer 1.

***GASFIL**
This input section is mandatory and specifies where the line data files are to be found and which gas lines are to be read from which file. These line data files are the unformatted direct access files produced as the output of the program HITLIN.
(1A) NFILE (integer) specifies the number of line data files to be used. NFILE must be less than or equal to MXFIL in the PARRAY statement.
(1B) MACH (integer) is a machine specifier that determines the record length of the line file. For a machine that has a 4 byte per word representation and defines the FORTRAN OPEN statement RECL in words, MACH= 1. This is the ANSII standard and is used under VAX/VMS. Other 4 byte per word machines specify the RECL in bytes, eg. IBM/RISC and MACH= 2. For the CRAY which has an 8 byte per word representation and defines RECL in bytes, MACH= 3. The same MACH value should be used here as was used by program HITLIN when the line file was written.

The following section is then repeated NFILE times.
(2A) FNAM (80 character string) is the file name of the line data file.
(3A) NGAS (integer) specifies the number of gases to be read from the data file. NGAS must be less than or equal to MXGAS in the PARRAY statement.
(4A) LGASES (integer) lists the NGAS molecular ID's of the gases to be read. These are the HITRAN molecular ID's given in Table 2.1.
(5A) LCHOSE (integer) lists the line version parameters to distinguish between the versions of duplicate lines on the data file. If LCHOSE= m then the most recent line versions up to and including the lines with status m are used. Only one version of any particular line will

be used in the line-by-line calculation. For example, program HITLIN may be used to merge the HITRAN data base (identified as having status 10) with line updates of a particular gas (identified as having status 11 say). Where HITLIN encounters a duplicate line, the line with the lower status number will have its status number set equal to the negative of itself. Thus the status number of a line on the HITRAN data base that has been updated will be set to −10. If the LCHOSE parameter for this gas is set equal to 11 then GENLN2 will use lines that have a status number greater than or equal to 10 and less than or equal to 11 or equal to −11, i.e. the lines used have a status number between 10 and LCHOSE inclusive or status equal to −LCHOSE. This will not include the HITRAN lines with status −10 that have been updated. However, if only HITRAN lines are required for the calculation the LCHOSE parameter can be set to 10 and only lines with status numbers of ±10 will be used.

***XSCFIL**

This section it not mandatory. It includes the input necessary to define an absorption calculation for those molecules for which cross-section data files are used.

(1A) **NXSFIL** (integer) is the number of cross-section data files to be used. NXSFIL must be less than or equal to MXFIL in the PARRAY statement. The following section is then repeated NXSFIL times.

(2A) **FXSNAM** (80 character string) is the cross-section data file name. The file **xsec.dat** is provide.

(3A) **NXSEC** (integer) is the number of gases for which cross-sections should be read from the cross-section file. NXSEC must be less than or equal to MXGAS in the PARRAY statement.

(4A) **LXSEC** (integer) is a list of molecular ID's of the gases for which cross-sections are to be read from the file. Table 2.1 shows the molecular ID-gas pairings being used. For paths that use cross-section data, the (3A) LINSHP parameter in *PTHPAR or *PTHFIL takes the value 'XSECTION'.

The cross-section data set is written in the NCAR format which will likely be adopted for the next edition of HITRAN on which these same cross-sections will be included. The file **xsec.dat** contains cross-sections for the molecules important for middle atmosphere studies. The header record and first line of the data are shown for the first few cross-section sets in Table 4.2.

***LINMIX**

Logical switch. This section is not mandatory and indicates that line coupling should be included where appropriate. Data is currently available for the CO_2 Q-branches at 617, 667, 720, 740, and 791 cm^{-1}, and is based on the CO_2 line parameters in file CO2MIX. In creating the line data file for use with a GENLN2 run with line coupling, the lines on CO2MIX should form the line input to HITLIN with the highest status number. The CO_2 LCHOSE value in *GASFIL should then be equal to this status number so that the required lines are selected. The 'VOIGTCO2' line shape should be used for the (3A) LINSHP parameter in *PTHPAR or *PTHFIL. In any computation with line coupling it is **ESSENTIAL** that the spectral range of the line-by-line calculation include all lines of the band for which coupling parameters have been calculated. This is to satisfy the line strength and coupling parameter sum rules (*Strow and Reuter*, 1988).

One and only one of the input sections *USEGRD, *GRDFIL, *DEFGRD or *RADIOM must be supplied. These sections perform the same task in setting up the spectral range to be investigated. The input wavenumber parameters are illustrated in Fig.4.1.

***USEGRD**

With *USEGRD the user supplies the wide mesh interval boundary wavenumber grid to cover the total spectral range of interest. Besides the passband wavenumber range, an adequate margin on either side should be included if a line-wing absorption calculation is to be per-

formed.
(1A) MINT (integer) is the number of wide mesh wavenumber intervals. MINT+1 must be less than or equal to MXINT in the PARRAY statement.
(2A) FBDY (real) is the array of MINT+1 wavenumber boundaries in cm^{-1}. The interval boundaries do not have to be of equal spacing, but the spacing should not be greater than a few wavenumbers.
(3A) NPL (integer) is index of the FBDY element corresponding to the wavenumber of the lower passband boundary.
(3B) NPU (integer) is index of the FBDY element corresponding to the wavenumber of the upper passband boundary.

*GRDFIL
This section allows the same input as the *USEGRD section to be read from an external file.
(1A) GRDFIL (80 character string) is the file name of the user's wide mesh interval boundary wavenumber file. The data on GRDFI should appear in exactly the same form as specified above for *USEGRD beginning at input record 1.

*DEFGRD
A default array of wide mesh interval boundary wavenumbers is calculated in this section. The intervals are calculated with constant spacing.
(1A) FMIN (real) is the minimum wavenumber cm^{-1} of any line to be considered in the GENLN2 calculation.
(1B) FPSL (real) is the lower passband wavenumber cm^{-1}.
(1C) FPSU (real) is the upper passband wavenumber cm^{-1}.
(1D) FMAX (real) is the maximum wavenumber cm^{-1} of any line to be considered in the GENLN2 calculation.
(1E) DELTA (real) is the constant wide mesh interval spacing in cm^{-1}. This should have a value of about 1 cm^{-1} for accurate interpolation of the wing absorption during the fine-pass stage.

*RADIOM
This section is used to input a radiometer spectral filter for the GENLN2 calculation. The option is primarily of use in performing radiative transfer studies using gas correlation instruments. The use of this option in Pressure Modulator Radiometer (PMR) calculations is described in Appendix 3.

*SPECTM
This section is mandatory if *USEGRD, *GRDFIL or *DEFGRD are used but must not be used with *RADIOM. It supplies the spectral calculation parameters illustrated in Fig.4.1.
(1A) FEXC (real) is the wavenumber range in cm^{-1} either side of a wide mesh interval for which the fine-pass calculation is performed. For wide mesh interval IPW a line-by-line absorption calculation is performed over the fine wavenumber grid FF(IPT,IPW) for line center wavenumbers WNUM cm^{-1} falling in the range
FBDY(IPW+NPL−1) − FEXC $\leq$ WNUM $\leq$ FBDY(IPW+NPL) + FEXC
(1B) FWIND (real) is the wavenumber range cm^{-1} either side of a wide mesh interval outside of which lines are not considered. The line wing absorption calculation is performed over the three wavenumber points FW(IP,IPW) of the wide mesh for line center wavenumbers WNUM cm^{-1} falling in the ranges
FW(IP,IPW) − FWIND $\leq$ WNUM $<$ FBDY(IPW+NPL−1) − FEXC and
FW(IP,IPW) +FWIND $\geq$ WNUM $>$ FBDY(IPW+NPL) + FEXC.
FWIND should be set equal to 25 cm^{-1} if a continuum absorption calculation is to be performed as discussed in Section 4.6.
(1C) NDIV (integer) determines the spectral resolution of the calculation. If NDIV$>$ 0 then the wide mesh interval is divided into NDIV fine mesh intervals over which the spectrum

is calculated. In this case NDIV+1 must be less than or equal to MXDIV in the PARRAY statement. The line-by-line calculation is then performed on a grid with spacing DELTA/NDIV cm^{-1}. If NDIV< 0 then the wide mesh interval IPW is divided such that the fine mesh grid spacing is set equal to the minimum path adjusted line width encountered in the wavenumber range

FBDY(IPW+NPL−1) − FEXC ≤ WNUM ≤ FBDY(IPW+NPL) + FEXC

divided by the absolute value of NDIV. This can lead to different fine grid spacing in different wide mesh intervals. If the calculated spectra are to be convolved with an instrument function in the GENGRP program, this option is not recommended (see the discussion of Section 5.3).

One at least of the input sections *PTHPAR or *PTHFIL must be supplied. The total number of paths from all sources must be less than or equal to MXPTH in the PARRAY statement.

***PTHPAR**

This section includes the information required to define the path conditions.

(1A) NPATH (integer) specifies the number of paths to be read from this section. The following section is then repeated NPATH times.

(2A) IDFIL (integer) indicates from which line data file or cross-section data file (IFILE value) the data for the path gas should be read.

(2B) IDGAS (integer) is the molecular ID of the path gas. This should be the same as one of the LGASES gases specified in section *GASFIL or one of the LXSEC gases in section *XSCFIL for file IDFIL.

(2C) IDISO (Integer) is the HITRAN isotope abundance ID. This is defined as follows; for IDISO= 0 lines of all isotopes of the gas are considered, for IDISO= 1 lines of the 1st most abundant isotope are taken, and so on. It should be remembered when specifying IDISO as anything other than 0 that the line strengths for a particular gas in the HITRAN data base are weighted according to the terrestrial atmospheric isotope abundance.

(2D) AMT (real) is the path integrated gas amount in units of $kg.moles.cm^{-2}$.

(2E) T (real) is the average path temperature in K.

(2F) P (real) is the average path pressure in atm.

(2G) PARTP (real) is the average partial pressure of the path gas in atm.

(2H) VEL (real) is the path velocity relative to the line of sight in $m.s^{-1}$ but is not yet implemented and should be set to zero.

3(A) LINSHP (8 character string) describes which line shape should be used for the path gas. At present the options are:

'LORENTZ'	The Lorentz line shape;
'DOPPLER'	The Doppler line shape;
'VOIGT'	The Voigt line shape using the *Humlicek* (1982) routine;
'VANVHUB'	The modified Van-Vleck Huber line shape (*Clough et al.*, 1980);
'VOIGTCO2'	The Voigt line shape modified for sub-Lorentzian CO_2 line wing behavior (*Cousin et al.*, 1985) and line coupling (*Edwards and Strow*, 1991);
'NEWSHAPE'	For the user to supply their own line shape routine NEWSHP;
'XSECTION'	If the calculation is to use cross-section data.

(3B) CONT (8 character string) determines if a continuum calculation is to be performed for this path and takes the value 'CON' or 'NOCON' appropriately. Continuum data are available for H_2O, CO_2, and the N_2 and O_2 pressure broadened bands.

***PTHFIL**

This section allows the same input as the *PTHPAR section to be read from an external file.

(1A) PFNAM (80 character string) is the file name of the user's path data file. The data on PFNAM should appear in exactly the same form as specified above for *PTHPAR beginning at input record 1. This section is used to input the path data calculated by program LAYERS which is already in the required format and can be used directly. The *PTHFIL section can

be included several times to allow for more than one LAYERS output path file to be used. The paths are then numbered sequentially in the order that they are read.

***MIXING**
This section defines the mixed path calculation. It is not mandatory and must not be supplied with *MIXFIL.
(1A) **NPMIX** (integer) specifies the number of mixed paths to be calculated. NPMIX must be less than or equal to MXPMX in the PARRAY statement. This is followed by the mixing table itself.
(2A) **IPMIX** (integer) is the mixed path number.
(2B) **TABMIX** (real) is the mixing table. The table has NPMIX rows and NPATH columns. The input fields can be up to 130 characters wide. Remember that NPATH here is the sum of all the paths read in the *PTHPAR and *PTHFIL sections. The entries for a particular mixed path may run over several lines of the input file, and input for a new mixed path must begin a new line.

It is often the case when mixing many paths together that a whole string of zeros or some other number must be entered in the table. In this case, an alternative to typing a number x n times is to type RxTn. So for example a line of input 0, 0, 0, 0, 0, could be written R0T5. This reduces the physical size of the mixing table and helps prevent input errors. The mixing table entries should be written either as integers or F format real numbers.

***MIXFIL**
This section allows the same input as the *MIXING section to be read from an external file. It is not mandatory and must not be specified with *MIXING.
(1A) **MIXFI** (80 character string) is the file name of the user's mixing table file. The data on MIXFI should appear in exactly the same form as specified above for *MIXING beginning at input record 1.

***RADNCE**
This section is included if a radiance calculation is required. It is not mandatory and must not be specified with *RADFIL.
(1A) **NATM** (integer) specifies the number of different radiance ('radiating atmosphere') calculations that are to be performed. NATM must be less than or equal to MXATM in the PARRAY statement. The following section is then repeated NATM times.
(2A) **IATM** (integer) is the atmosphere index.
(2B) **IVIEW** (integer) is the viewing parameter. This can take two values which determine the boundary condition to be used in the radiation transfer equation as discussed in Section 4.8. If IVIEW= 1 then the radiance at the inward boundary to the first layer is set equal to zero. This would be appropriate to a limb emission calculation. If IVIEW= 2 a radiating surface boundary condition is applied. This would be appropriate for a nadir sounding problem where the surface emission term is non-negligible.
(2C) **IEMS** (integer) is the layer emission parameter. If IEMS= 1 then a single optical depth is later specified for each layer and this is used to determine both the layer transmittance and emission, i.e. $\psi(\nu)_l$ and $\phi(\nu)_l$ in Eqn.(4.29) are identical. Setting IEMS= 2 specifies an emission calculation and two optical depths are required for each layer, one to determine the layer transmittance $\psi(\nu)_l$, and the other to determine the layer emission $\phi(\nu)_l$.
(2D) **NLAY** (integer) specifies the number of layers for the atmosphere. NLAY must be less than or equal to MXLAY in the PARRAY statement.
(2E) **LAYSP** (integer) indicates if the set of indices that follow (LAYER) for specifying the layer optical depth for the transmittance calculation $\psi(\nu)_l$ (and emission calculation if IEMS= 1) refer to path numbers, LAYSP= 1, or mixed path numbers, LAYSP= 2.
(2F) **LAYER** (integer) are a list of NLAY indices referring to the path numbers (LAYSP= 1) or mixed path numbers (LAYSP= 2) whose optical depth are to be used to define the optical

depths $\psi(\nu)_l$ of the layers for the layer transmittance calculation. The indices defining each layer should be listed in the direction of radiation travel through the atmosphere.

If IVIEW= 2 then the parameters defining the radiating boundary surface come next. If IVIEW= 1 this section is absent.
(3A) **TBDY** (real) is the temperature of the atmospheric boundary furthest away from the reflecting surface. For example in the case of a nadir viewing satellite, TBDY= 2.96 K the temperature of cold space and the effective top of the atmosphere. This corresponds to the quantity T_b in Eqn.(4.26).
(3B) **TINIT** (real) is the boundary surface temperature corresponding to T_s in Eqn.(4.26).
(3C) **EMSTY** (real) is the surface emittance corresponding to ϵ in Eqn.(4.26).

If IEMS= 2 then a different set of optical depths, $\phi(\nu)_l$ in Eqn.(4.29), are required to define the layer emission. If IEMS= 1 then this section is absent.
(4A) **LEMSP** (integer) indicates if the set of indices that follow (LAYEMS) for specifying the layer optical depth $\phi(\nu)_l$ for the emission calculation refer to path numbers, LEMSP= 1, or mixed path numbers, LEMSP= 2.
(4B) **LAYEMS** (integer) are a list of NLAY indices referring to the path numbers (LEMSP= 1) or mixed path numbers (LEMSP= 2) whose optical depths are to be used to define the optical depths $\phi(\nu)_l$ of the layers for the layer emission calculation. The indices defining each layer should be listed in the direction of radiation travel through the atmosphere.

*RADFIL

This section allows the same input as the *RADNCE section to be read from an external file. It is not mandatory and must not be specified with *RADNCE.
(1A) **RADFI** (80 character string) is the file name of the user's radiance input data file. The data on RADFI should appear in exactly the same form as specified above for *RADNCE beginning at input record 1.

*OUTPUT

If *OUTPUT is specified then an unformatted output file will be written. It is not mandatory. This file is in addition to the formatted summary output data file that is assigned prior to execution and for which output data selection is made in *TITLES. As this file is for graphics use, there is provision for output of the point spectra calculated on the fine wavenumber grid as well as the binned spectra integrated over the wide mesh intervals.
(1A) **OPFNAM** (80 character string) is the file name of the output file.
(2A) **IDAT** (integer) is an output selection parameter similar to that used in the *TITLES section. For the different output categories this now takes the values:

1. for the path point transmittance spectra;
2. for the path integrated transmittance spectra;
3. for the mixed path point transmittance spectra;
4. for the mixed path integrated transmittance spectra;
5. for the radiating atmosphere layer point transmittance spectra;
6. for the radiating atmosphere layer integrated transmittance spectra;
7. for the radiating atmosphere layer point radiance spectra;
8. for the radiating atmosphere layer integrated radiance spectrum.

(3A) **IATM** (integer) specifies the relevant atmosphere number (radiance calculation number) when IDAT> 4. For IDAT< 4 it is absent. Setting IATM< 0 results in spectra for all atmospheres being written.
(3B) **NP** (integer) specifies the number of paths, mixed paths or layers to be written. If NP< 0 then all are written.
(4A) **IOPGR** (integer) gives the list of NP (if NP> 0) path, mixed path, or layer numbers to be written. 4A is absent if NP< 0. The above input parameters are repeated as required each time beginning at the value of IDAT.

***INTEGN**
Logical switch, not mandatory. Specifying *INTEGN results in the fine grid transmittances and radiances being binned and integrated over the wide mesh interval.

***ENDINP**
Mandatory specifier signalling the end of the input file.

4.11 GENLN2 Implementation

The execution of the GENLN2 program is performed with the following operations:

1. Program GENLN2 and its subroutines are compiled and linked.
2. The users input file is assigned to unit 4 and the formatted summary output data file is assigned to unit 30.
3. The program is executed.

Program GENLN2 uses the PARRAY parameter file (Table 3.3) to set the maximum array dimensions.

MXMOL - Highest molecular ID used in the calculation. This parameter was also used by program LAYERS. Currently MXMOL=63.

MXPTH - Maximum number of paths for calculation. This parameter was also used by program LAYERS.

MXFIL - Maximum number of line data files or cross-section data files (whichever is greater) that will be used.

MXISO - Maximum molecular isotope ID used. This currently follows the HITRAN definition where the maximum number of isotopic species MXISO=8.

MXGAS - Maximum number of gases for which line or cross-section data will be read from any one data file.

MXPMX - Maximum number of mixed paths to be calculated.

MXINT - Maximum number of elements in the the array FBDY of wide mesh boundary wavenumbers. This is equal to the total number of wide mesh intervals (passband range plus the wing regions) plus one.

MXDIV - Maximum number of fine mesh boundary wavenumbers per wide mesh. This is equal to the maximum number of fine meshes plus one.

MXLIN - Maximum number of lines that will be stored in the fine-pass line buffer at any time. This is equal to the maximum number of lines that at any time fall in the range from the wide mesh lower boundary − FEXC to the upper boundary + FEXC. A value of MXLIN=4000 will be sufficient for most calculations.

MXXPT - Maximum number of data points for any molecular cross-section data set. If the **xsec.dat** data file is used MXXPT=12808.

MXTEM - Maximum number of temperature molecular cross-section sets for any one molecular absorption band. If the **xsec.dat** data file is used MXTEM=6.

MXPDM - This parameter should be set equal to the maximum value of MXPTH, MXPMX, and

MXLAY (described below).

If a transmittance only calculation is required the following parameters that define the maximum dimensions for the arrays used in the radiance calculation can be set to 1 to save space.

MXLAY - Maximum number of atmospheric layers in any radiance calculation atmosphere.

MXATM - Maximum number of radiance calculation atmospheres.

MXIRD - The same as MXINT but used for the radiance calculation arrays.

MXDRD - The same as MXDIV but used for the radiance calculation arrays.

The input/output FORTRAN unit numbers used by program LAYERS are:

Unit 4. Input
Used for reading the input file that defines the GENLN2 task. This unit number must be assigned outside the FORTRAN program.

Unit 6. Output
Used for writing a calculation progress status.

Unit 10. Input
Used to input the data from the input *KEYWORD sections that read subsidiary input files. These are the users wide mesh boundary wavenumber data in *GRDFIL, the path data file in *PTHFIL, the mixing table file in *MIXFIL and the radiance data file in *RADFIL.

Units 11 — (11+NFIL–1). Input
Used for reading line parameters from the NFIL line data files.

Units 20 — (20+NXSFIL–1). Input
Used for reading cross-section data from the NXSFIL cross-section data files.

Unit 30. Output
Used for the output of the formatted summary data file. This unit number must be assigned outside the FORTRAN program.

Unit 31. Output
Used for the output of the unformatted spectral data file. This is the file specified in the *OUTPUT section of the input file.

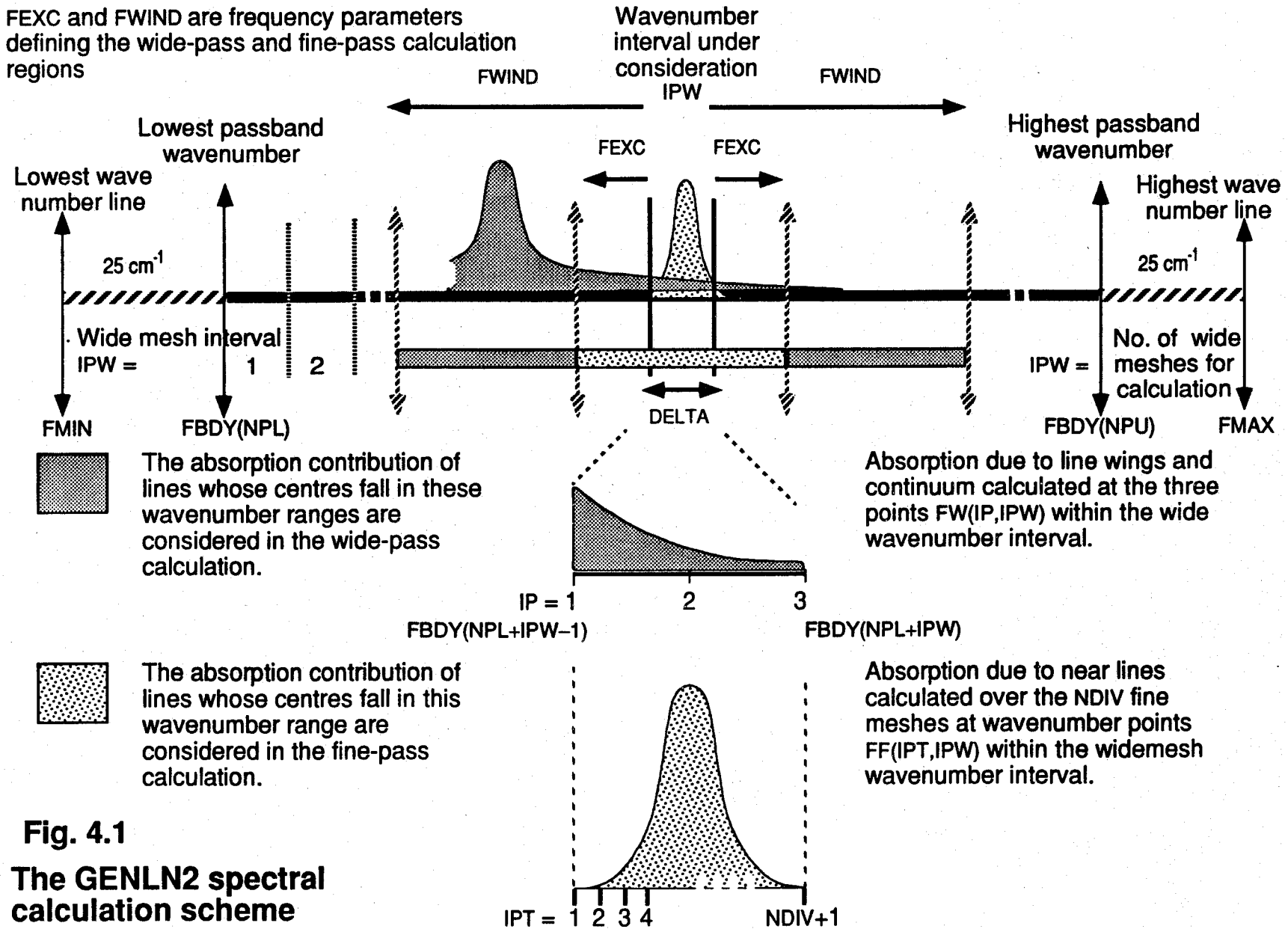
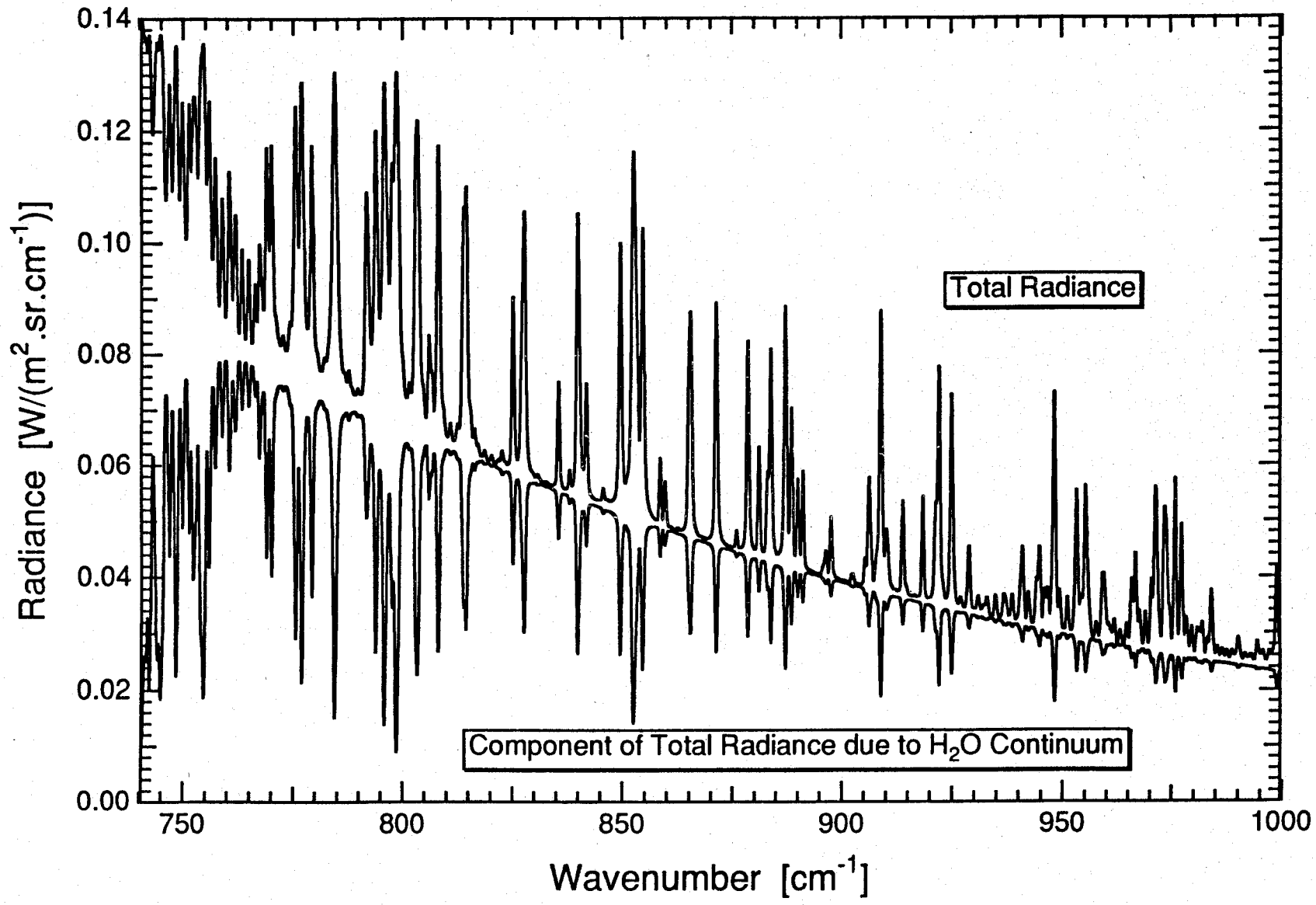


Fig. 4.1

The GENLN2 spectral calculation scheme

Fig.4.2. Uplooking Radiance in a Tropical Atmosphere.



Mixed Path number	Path Number 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	1.0	1.0	1.0	1.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0
3	0.0	0.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0	1.0	0.0	0.0	1.0	1.0	1.0
4	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
5	0.0	0.0	0.0	1.4	1.4	0.0	0.0	0.0	1.4	1.4	0.0	0.0	0.0	1.4	1.4
6	0.0	1.4	1.4	1.4	1.4	0.0	1.4	1.4	1.4	1.4	0.0	1.4	1.4	1.4	1.4
7	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
8	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0
9	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0
10	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0
11	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	1.0

Purpose of the Mixed Paths:

1. H_2O only Mixed Path through all layers of the atmosphere
2-4. Mixed Paths from different levels to the top of the atmosphere for all gases
5-6. Slant Mixed Path at θ=45 deg from different levels to top of the atmosphere for all gases
7-11. Single layer Mixed Paths for all gases

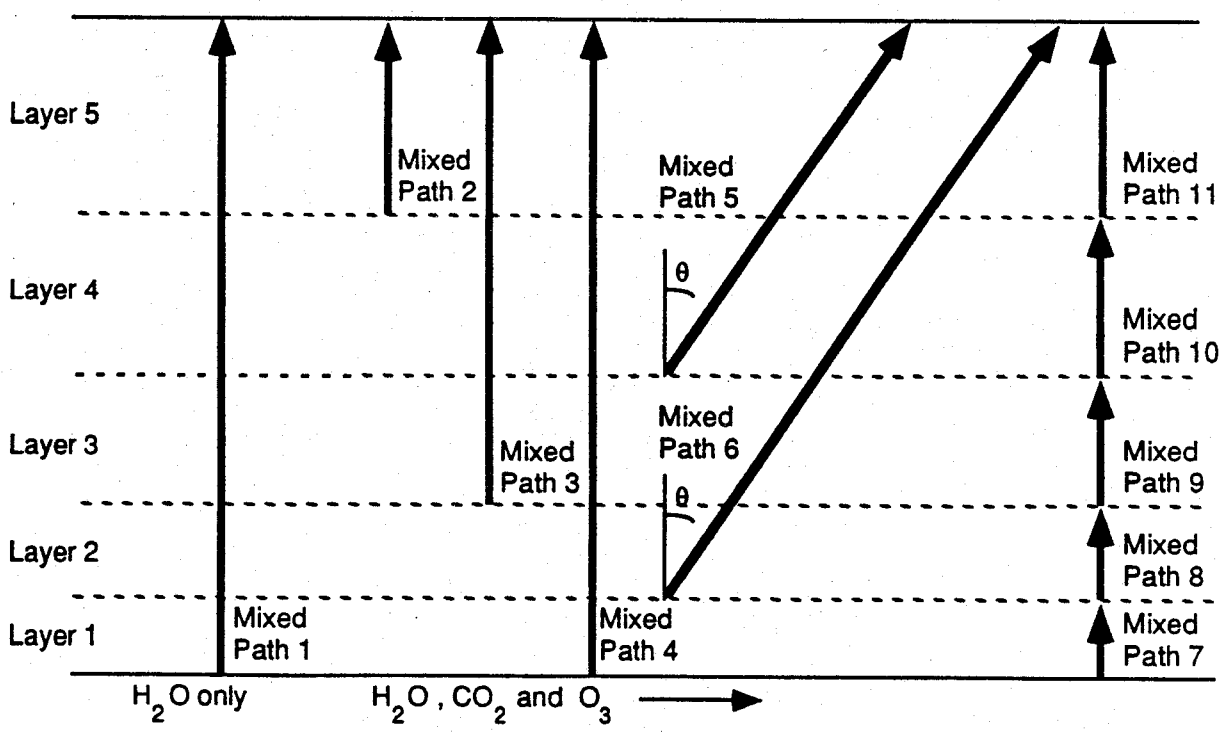


Fig. 4.3
Illustration of Mixed Paths formed from the Paths of Fig. 3.1 and defined by the mixing table above

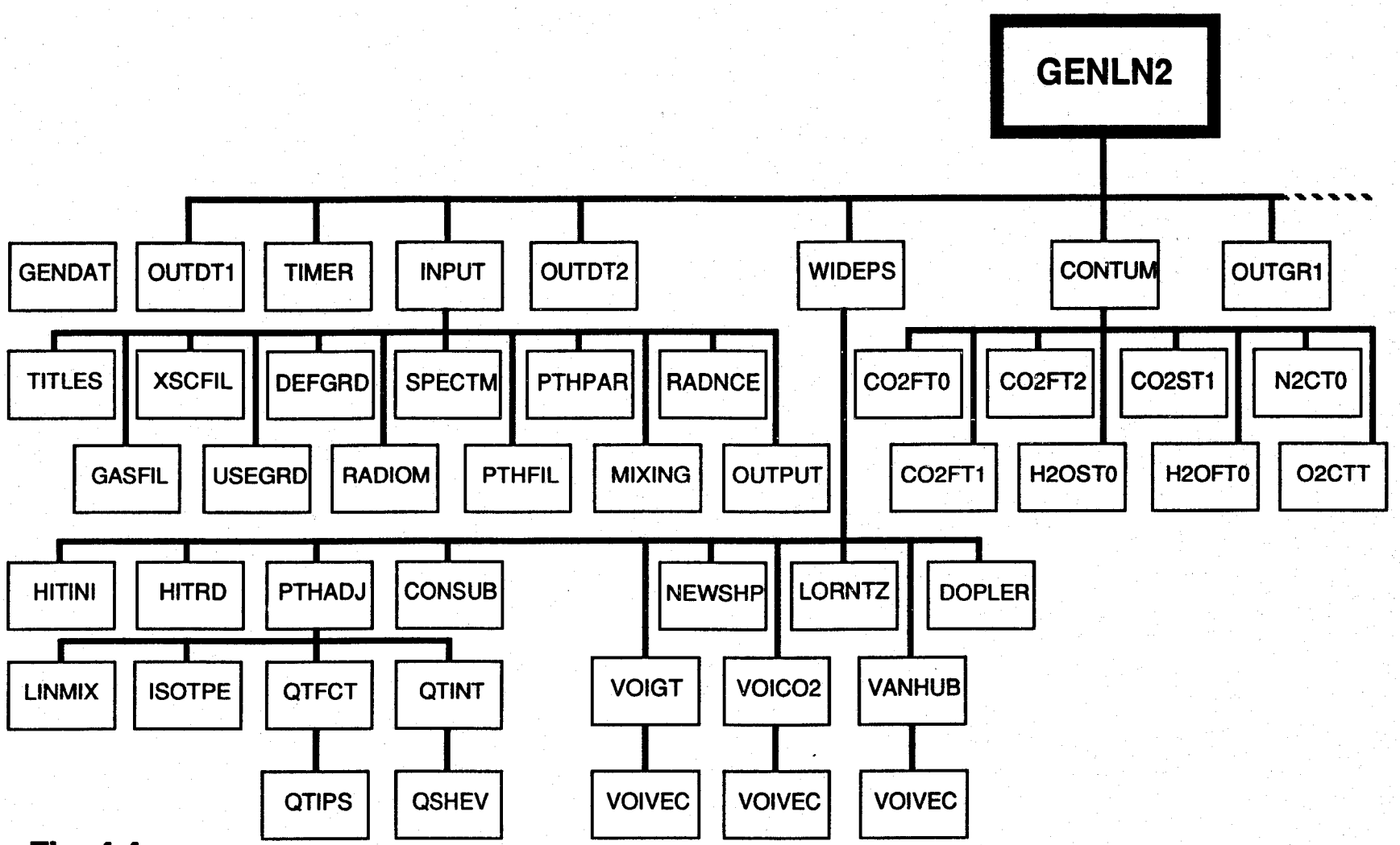


Fig. 4.4

Program structure for the GENLN2 subroutines

continued over....

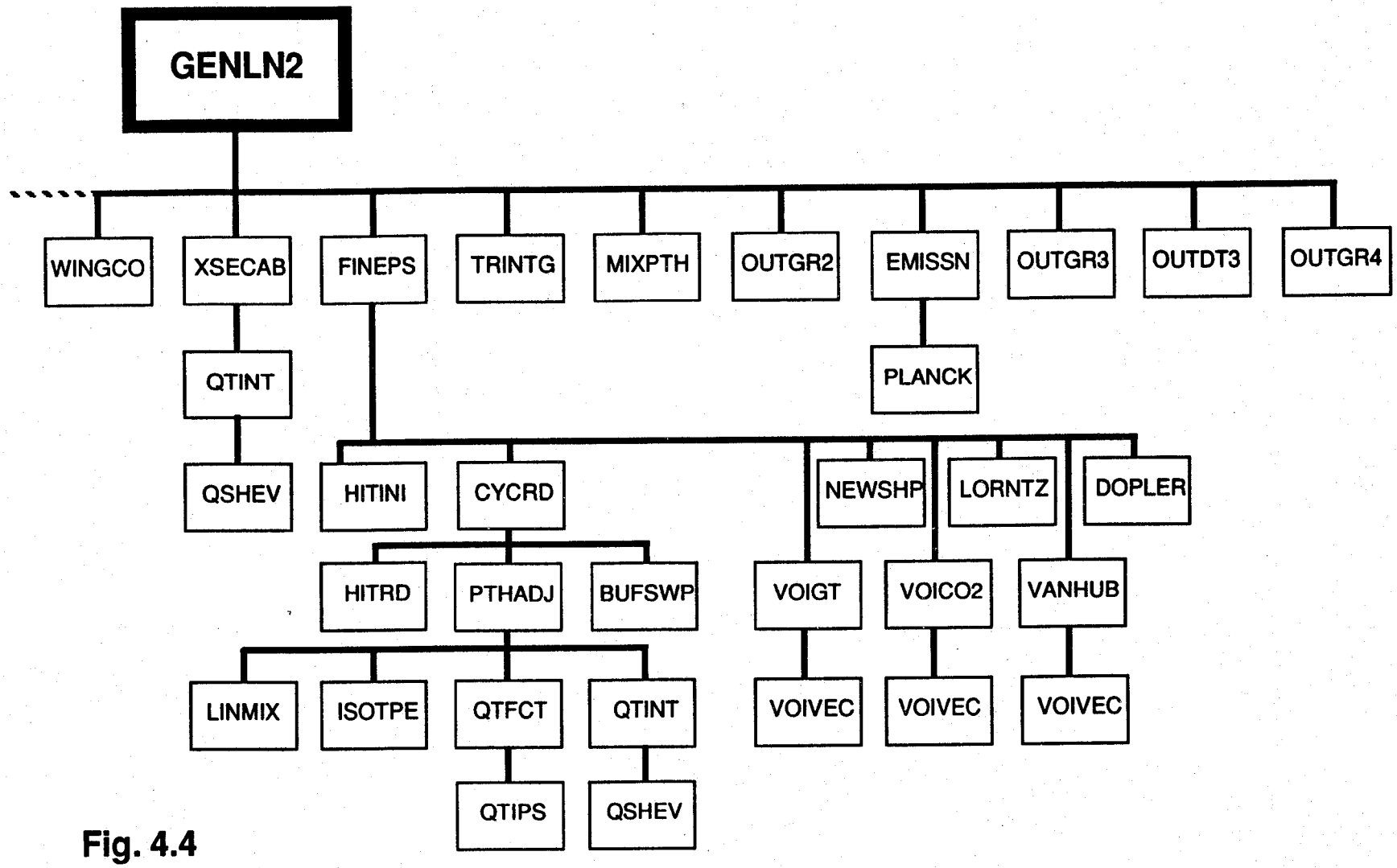


Fig. 4.4

Program structure for the GENLN2 subroutines

.....continued

Table 4.1 Program GENLN2 reference input file

genln2_input.ref


```
!                    ****************************************
!                    *                                      *
!                    *          PROGRAM GENLN2: INPUT FILE  *
!                    *          --------------------------  *
!                    *  INPUT FILE FOR THE GENLN2 LINE-BY-LINE *
!                    *  COMPUTER MODEL. CALCULATES ATMOSPHERIC *
!                    *  TRANSMITTANCE AND RADIANCE.         *
!                    *  VERSION 3.0: D.P. EDWARDS 21/08/90  *
!                    *                                      *
!                    ****************************************
!                                                          INPUT PARAMETER NAME
!-----------------------------------------------------------------------------
!..TITLE INFORMATION AND SUMMARY OUTPUT SPECIFICATION FOR THIS GENLN2 RUN
!..(*TITLES) [MANDATORY]
*TITLES
!
!      1A. Title of this GENLN2 run (40 characters MAX) :                  TITLE
TITLE
!
!      2A. Passband average spectral values only are printed in
!          formatted summary output file if logical is set true:          AVER
!      2B. Mixing table not printed if logical is set true:               MXER
AVER, MXER
!
!      Data to be printed in the formatted summary output file is
!      specified by the IDAT parameter for the following categories:-
!      IDAT = 1  Path integrated transmittance spectrum.
!           = 2  Mixed path integrated transmittance spectrum.
!           = 3  Radiating atmosphere layer integrated
!                transmittance and radiance spectra.
!      The following section is repeated for each required IDAT.
!----------
!      3A. Index (1,2 or 3 above):                                         IDAT
IDAT
!
!      If  IDAT = 1 or IDAT = 2:
!      4A. No. of paths or mixed paths to be printed: NP;
!          if all paths are to be print set NP<0.
!      Else if IDAT=3:
!      4A. Atmosphere no. for printing:                                    IATM
!          if all atmospheres are to be printed set IATM<0.
!      4B. no. of layers to be printed:                                      NP
!          if all layers are to be printed set NP<0.
IATM(if IDAT=3), NP
!
!      For all IDAT:
!      5A. List of path, mixed path or layer nos. for printing;
!          only required if NP>0:                  (IOPDT(IDAT,IATM,I),I=1,NP)
IOPDT(IDAT,IATM,1), IOPDT(IDAT,IATM,2), .... IOPDT(IDAT,IATM,NP)
!----------
IDAT
IATM(if IDAT=3), NP
IOPDT(IDAT,IATM,1), IOPDT(IDAT,IATM,2), .... IOPDT(IDAT,IATM,NP)
!----------
etc.
!----------
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..THE GAS LINE DATA FILE(S) TO BE USED (*GASFIL) [MANDATORY]
*GASFIL
!
!      1A. No. of line data files to be read:                             NFILE
!      1B. Machine specifier, determines record length:                    MACH
!          MACH=1: 4 byte/word, OPEN RECL in words (eg. VAX, ANSII stand)
!          MACH=2: 4 byte/word, OPEN RECL in bytes (eg. IBM RISC)
!          MACH=3: 8 byte/word, OPEN RECL in bytes (eg. CRAY)
!          This should be the same as was used in HITLIN
NFILE, MACH
!
!      For each file (IFILE=1,NFILE) 4 input records
!----------
!      2A. Filename of line data file:                                  FNAM(IFILE)
FNAM(1)
!
!      3A. No. of gases to be read from this file:                      NGAS(IFILE)
NGAS(1)
!
!      4A. Molecular ID's of the gas(es) to be read:
!                                        (LGASES(IFILE,IGAS),IGAS=1,NGAS(IFILE))
LGASES(1,1), LGASES(1,2), ....   LGASES(1,NGAS(1))
!
!      5A. Line data version(s) to be chosen:
!                                        (LCHOSE(IFILE,IGAS),IGAS=1,NGAS(IFILE))
LCHOSE(1,1), LCHOSE(1,2), ....   LCHOSE(1,NGAS(1))
!----------
FNAM(2)
NGAS(2)
LGASES(2,1), LGASES(2,2), ....   LGASES(2,NGAS(2))
LCHOSE(2,1), LCHOSE(2,2), ....   LCHOSE(2,NGAS(2))
!----------
       |
       |
!----------
FNAM(NFILE)
NGAS(NFILE)
LGASES(NFILE,1), LGASES(NFILE,2), ....   LGASES(NFILE,NGAS(NFILE))
LCHOSE(NFILE,1), LCHOSE(NFILE,2), ....   LCHOSE(1,NGAS(NFILE))
!----------
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..THE GAS CROSS-SECTION DATA FILE(S) TO BE USED (*XSCFIL) [NOT MANDATORY]
*XSCFIL
!
!      1A. No. of xsec data files to be read:                             NXSFIL
NXSFIL
!
!      For each file (IFILE=1,NXSFIL) 3 input records
!----------
!      2A. Filename of xsec data file:                               FXSNAM(IFILE)
FXSNAM(1)
!
!      3A. No. of gas xsecs to be read from this file:               NXSEC(IFILE)
NXSEC(1)
!
!      4A. Molecular ID's of the xsec gas(es) to be read:
!                                        (LXSEC(IFILE,IGAS),IGAS=1,NXSEC(IFILE))
LXSEC(1,1), LXSEC(1,2), .... LXSEC(1,NXSEC(1))
!----------
FXSNAM(2)
NXSEC(2)
LXSEC(2,1), LXSEC(2,2), .... LXSEC(2,NXSEC(2))
!----------
       |
       |
!----------
FXSNAM(NXSFIL)
NXSEC(NXSFIL)
LXSEC(NXSFIL,1), LXSEC(NXSFIL,2), .... LXSEC(NXSFIL,NXSEC(1))
```

Table 4.1 Program GENLN2 reference input file genln2_input.ref


```
!----------
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..LINE COUPLING CALCULATION FOR FLAGGED LINES ON THE DATABASE (*LINMIX)
!..[NOT MANDATORY]
*LINMIX
!       Logical switch. When present line mixing is include in the calculation.
!
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!
!ONE AND ONLY ONE  of *USEGRD, *GRDFIL, *DEFGRD or *RADIOM must be supplied.
!
!-----------------------------------------------------------------------------
!..USER'S WIDE MESH BOUNDARY WAVENUMBER GRID (*USEGRD)
!..[MANDATORY if one of *GRDFIL, *DEFGRD or *RADIOM is not supplied]
*USEGRD
!
!       1A. No. of wide mesh intervals:                                  MINT
MINT
!
!       2A. Array of MINT+1 boundary wavenumbers (cm-1): (FBDY(IPW),IPW=1,MINT+1)
FBDY(1), FBDY(2), FBDY(3), .... FBDY(MINT), FBDY(MINT+1)
!
!       3A. The FBDY index IPW value specifying the wavenumber
!           boundary corresponding to the lower integration
!           (pass-band) frequencies:                                      NPL
!       3B. upper integration (pass-band) wavenumber:                     NPU
NPL , NPU
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..USER'S WIDE MESH BOUNDARY WAVENUMBER GRID ON EXTERNAL FILE (*GRDFIL)
!..[MANDATORY if one of *USEGRD, *DEFGRD or *RADIOM is not supplied]
*GRDFIL
!
!       1A. Filename of the users wide mesh boundary wavenumber file:    GRIDFI
!
!       The file GRDFI then contains the same information
!       as the *USEGRD section beginning with input record 1
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..DEFAULT CALCULATION OF WIDE MESH BOUNDARY WAVENUMBER GRID (*DEFGRD)
!..[MANDATORY if one of *USEGRD, *GRDFIL or *RADIOM is not supplied]
*DEFGRD
!
!       1A. The minimum wavenumber to be considered (cm-1):               FMIN
!       1B. the lower integration (passband) wavenumber (cm-1):           FPSL
!       1C. the upper integration (passband) wavenumber (cm-1):           FPSU
!       1D. the maximum wavenumber to be considered (cm-1):               FMAX
!       1E. the wide mesh constant wavenumber interval spacing (cm-1):   DELTA
FMIN, FPSL, FPSU, FMAX, DELTA
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..CALCULATION OF SPECTRA CONVOLED WITH RADIOMETER RESPONSE FILTER (*RADIOM)
!..[MANDATORY if one of *USEGRD, *GRDFIL or *DEFGRD is not supplied]
*RADIOM
!
!       1A. The wavenumber range either side of a wide mesh interval for
!           which a fine grid line-by-line calculation is performed (cm-1):  FEXC
!       1B. the wavenumber range either side of a wide mesh interval
!           outside of which lines are not considered (cm-1):            FWIND
!       1C. the width of the wide mesh interval to be used in the wing
!           regions either side    the passband (cm-1):                 DELWNG
FEXC, FWIND, DELWNG
!
!       2A. The filename of the radiometer response profile:              RESFI
RESFI
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..PARAMETERS DEFINING THE SPECTRAL CALCULATION REGIONS (*SPECTM)
!..[MANDATORY with *USEGRD, *GRDFIL or *DEFGRD.
!..Must not appear if *RADIOM is supplied]
*SPECTM
!       1A. The wavenumber range either side of a wide mesh interval for
!           which a fine grid line-by-line calculation is performed (cm-1):  FEXC
!       1B. the wavenumber range either side of the current interval
!           outside of which lines are not considered (cm-1):            FWIND
!       1C. the parameter specifying the division of the wide mesh
!           wavenumber interval to produce the fine mesh wavenumber grid:  NDIV
FEXC, FWIND, NDIV
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!
!ONE AT LEAST of *PTHFIL or *PTHPAR must be supplied.
!
!-----------------------------------------------------------------------------
!..PATH PARAMETERS (*PTHPAR)
*PTHPAR
!
!       1A. No. of paths to be read from this file:                      NPATH
NPATH
!
!       For each path (IPATH=1,NPATH) 2 input records
!----------
!       Path parameters required are:-
!       2A. The file (IFILE) off of which the path gas is to be read:IDFIL(IPATH)
!       2B. the molecular ID of the path gas:                       IDGAS(IPATH)
!       2C. the isotope abundance ID of the path gas:               IDISO(IPATH)
!       2D. the amount of gas in the path (kg.moles/cm2):             AMT(IPATH)
!       2E. the average path temperature (K):                           T(IPATH)
!       2F. the total gas pressure of the path (atm):                   P(IPATH)
!       2G. the partial pressure of the path gas (atm):             PARTP(IPATH)
!       2H. the gas velocity (m/s) not used at present:               VEL(IPATH)
IDFIL(IPATH), IDGAS(1), IDISO(1), AMT(1), T(1), P(1), PARTP(1), VEL(1)
!
!       3A. Line shape to be used for this path:                    LINSHP(IPATH)
!       3B. Continuum specifier for this path 'CON' or 'NOCON':      CONT(IPATH)
!       Character variables must be enclosed by quotes.
LINSHP(1), CONT(1)
!----------
IDFIL(2), IDGAS(2), IDISO(2), AMT(2), T(2), P(2), PARTP(2), VEL(2)
LINSHP(2), CONT(2)
!----------
        |
        |
!----------
IDFIL(NPATH), IDGAS(NPATH),IDISO(NPATH),AMT(NPATH),T(NPATH),
P(NPATH),PARTP(NPATH),VEL(NPATH)
LINSHP(NPATH), CONT(NPATH)
!----------
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..PATH PARAMETERS READ FROM EXTERNAL FILE, EG. LAYERS OUTPUT FILE (*PTHFIL)
*PTHFIL
!
!       1A. File name of external path parameter file:                   PFNAM
PFNAM
!
```

Table 4.1 Program GENLN2 reference input file genln2_input.ref


```
!       File PFNAM then contains the same information as the
!       *PTHPAR section beginning with input record 2
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!
!ONLY ONE (if either) of the following *MIXING or *MIXFIL should be supplied
!
!-----------------------------------------------------------------------------
!..MIXING PATHS TO FORM ATMOSPHERIC MIXED PATHS (*MIXING) [NOT MANDATORY]
*MIXING
!
!       1A. No. of mixed paths to be calculated:                          NPMIX
NPMIX
!
!       Mixing table is of length NPATH and depth NPMIX:
!       (remember NPATH is the sum of the number of paths read
!       in the *PTHPAR and the *PTHFIL sections)
!       The required mixing table parameters are:-
!       2A. The mixed path index:                                         IPMIX
!       2B. the mixing table:                 (TABMIX(IPATH,IPMIX),IPATH=1,NPATH))
!       Each new mixed path must begin a new line, and the
!       input field must not exceed 130 characters.
1,      TABMIX(1,1)     TABMIX(2,1)     TABMIX(3,1)     ....  TABMIX(NPATH,1)
2,      TABMIX(1,2)     TABMIX(2,2)     TABMIX(3,2)     ....  TABMIX(NPATH,2)
3,      TABMIX(1,3)     TABMIX(2,3)     TABMIX(3,3)     ....  TABMIX(NPATH,3)
        |
        |
NPMIX, TABMIX(1,NPMIX) TABMIX(2,NPMIX) TABMIX(3,NPMIX) .... TABMIX(NPATH,NPMIX)
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..MIXING TABLE READ FROM EXTERNAL FILE (*MIXFIL) [NOT MANDATORY]
*MIXFIL
!
!       1A. Name of external file containing mixing table:                MIXFI
MIXFI
!
!       File MIXFI then contains the same information
!       as in the *MIXING section beginning at input record 1
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..RADIANCE CALCULATION (*RADNCE) [NOT MANDATORY]
*RADNCE
!
!       1A. No. of radiating atmospheres to be calculated:                 NATM
NATM
!       For each atmosphere (IATM=1,NATM) 3 input records
!----------
!       Layer table data consists of the following:-
!       2A. The radiating atmosphere index:                                IATM
!       2B. the viewing parameter:                                   IVIEW(IATM)
!       2C. the layer emission parameter:                             IEMS(IATM)
!       2D. the no. of layers in the atmosphere:                      NLAY(IATM)
!       2E. path or mixed path specifier for total layer absorption:  LAYSP(IATM)
!       2F. the path (LAYSP(IATM)=1) or mixed path nos.(LAYSP(IATM)=2)
!           to be used to specify the layer total absorption in order
!           of radiation travel:            (LAYER(ILAY,IATM),ILAY=1,NLAY(IATM))
1, IVIEW(1), IEMS(1), NLAY(1), LAYSP(1),
   LAYER(1,1) LAYER(2,1) LAYER(3,1) .... LAYER(NLAY(1),1)
!
!       If IVIEW(IATM)=2 then the initiating surface parameters are supplied:
!       3A. Atmospheric boundary temperature (K):                     TBDY(IATM)
!       3B. temperature of the initiating surface:                   TINIT(IATM)
!       3C. emissivity of initiating surface:                        EMSTY(IATM)
TBDY(1), TINIT(1), EMSTY(1)
!
!       If IEMS(IATM)=2 different paths/mixed paths can to be used for
!       layer emission to those used for layer transmittance:
!       4A. path or mixed path specifier for emission layer absorption:LEMSP(IATM)
!       4B. the path (LEMSP(IATM)=1) or mixed-path nos.(LEMSP(IATM)=2)
!           to be used to specify the layer emission in order
!           in order of radiation travel:   (LAYEMS(ILAY,IATM),ILAY=1,NLAY(IATM))
LEMSP(1), LAYEMS(1,1) LAYEMS(2,1) LAYEMS(3,1) .... LAYEMS(NLAY(1),1)
!----------
2, IVIEW(2), IEMS(2), NLAY(2), LAYSP(2),
   LAYER(1,2) LAYER(2,2) LAYER(3,2) .... LAYER(NLAY(2),2)
TBDY(2), TINIT(2), EMSTY(2)
LEMSP(2), LAYEMS(1,2) LAYEMS(2,2) LAYEMS(3,2) .... LAYEMS(NLAY(2),2)
!----------
        |
        |
!----------
NATM, IVIEW(NATM), IEMS(NATM), NLAY(NATM), LAYSP(NATM),
      LAYER(1,NATM) LAYER(2,NATM) LAYER(3,NATM) .... LAYER(NLAY(NATM),NATM)
TBDY(NATM), TINIT(NATM), EMSTY(NATM)
LEMSP(NATM),
      LAYEMS(1,NATM) LAYEMS(2,NATM) LAYEMS(3,NATM) .... LAYEMS(NLAY(NATM),NATM)
!----------
!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..RADIANCE DATA READ FROM EXTERNAL FILE (*RADFIL) [NOT MANDATORY]
*RADFIL
!
!       1A. Name of external file containing mixing table:                RADFI
RADFI
!
!       File RADFI then contains the same information
!       as in the *RADNCE section beginning at input record 1
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..INTEGRATION SWITCH (*INTEGN) [NOT MANDATORY]
*INTEGN
!       Logical switch. When present the transmittance and radiance
!       spectra are integrated over each wide mesh interval.
!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..UNFORMATTED OUTPUT FILE SPECIFICATION (*OUTPUT) [NOT MANDATORY]
*OUTPUT
!
!       1A. File name of output file:                                     OPFNAM
OPFNAM
!
!       Data to be output is specified by IDAT parameter
!       for the following categories:-
!       IDAT= 1  Path point transmission spectrum;
!           = 2  Path integrated transmission spectrum;
!           = 3  Mixed path point transmission spectrum;
!           = 4  Mixed path integrated transmission spectrum;
!           = 5  Layer point transmission spectrum;
!           = 6  Layer integrated transmission spectrum;
!           = 7  Layer point radiance spectrum;
!           = 8  Layer integrated radiance spectrum.
!       The following section is repeated for each required IDAT.
!----------
!       2A. Index (1 thru 8 above):                                       IDAT
IDAT
!
!       For IDAT = 1, 2, 3 or 4:
!       3A. no. of paths or mixed paths to be output :                      NP
```

Table 4.1 Program GENLN2 reference input file genln2_input.ref


```
!           if all paths are to be output set NP<0.
!       For IDAT = 5, 6, 7 or 8:
!       3A. atmosphere no. for output:                                  IATM
!           if all atmospheres are to be output set IATM<0.
!       3B. no. of layers to be output:                                  NP
!           if all layers are to be output set NP<0.
IATM(if IDAT>4), NP
!
!       For all IDAT:
!       4A. List of path, mixed path or layer nos. for output;
!           only required if NP>0:                    (IOPGR(IDAT,IATM,I),I=1,NP)
IOPGR(IDAT,IATM,1), IOPGR(IDAT,IATM,2), .... IOPGR(IDAT,IATM,NP)
!----------
IDAT
IATM(if IDAT>4), NP
IOPGR(IDAT,IATM,1), IOPGR(IDAT,IATM,2), .... IOPGR(IDAT,IATM,NP)
!----------
etc.
!----------
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..END OF GENLN2 INPUT (*ENDINP) [MANDATORY]
*ENDINP
!!!!!!! End of input data to GENLN2 !!!!!!!
```

Table 4.2 Format of the molecular cross-section data file

xsec.dat


```
The cross-section data files are set out according to:
*** MOL NT
(A3,I7,I10)
CHARID FMIN FMAX NOPT TX HEADER
(A10,F10.4,F10.4,I10,F10.1,A50)
XDATA(I),I=1,NOPT
(1P10E10.3)
where:

***     Each cross-section set begins with this flag. For
        the same molecule there is a separate cross-section
        set for each band and each band starts with this
        header.
MOL     Is the molecular ID.
NT      Number of temperature cross-section sets.
CHARID  Molecule character identifier (chemical name).
FMIN    Wavenumber of first cross-section data point.
FMAX    Wavenumber of last cross-section data point.
NOPT    Number of cross-section data points.
TX      Temperature at which data was taken [K].
HEADER  Header information about the cross-section includes:
        pressure at which data was taken (Torr),
        laboratory at which data was taken,
        common name of the molecule.
XDATA   Cross-section data in units of [cm2/molecule].

The header record and 1st data line for some example
cross-section sets:

***     51          6
  CCL3F     830.0010  859.9960      2023     293.0    0.0000  NCAR      CFC-11
 3.510E-19 3.450E-19 3.290E-19 3.390E-19 3.480E-19 3.380E-19 3.400E-19 3.510E-19 3.510E-19 3.540E-19
etc.
  CCL3F     830.0010  859.9960      2023     273.0    0.0000  NCAR      CFC-11
 2.830E-19 2.960E-19 2.950E-19 2.830E-19 2.740E-19 2.640E-19 2.700E-19 2.860E-19 2.900E-19 3.030E-19
etc.
  CCL3F     830.0010  859.9960      2023     253.0    0.0000  NCAR      CFC-11
 2.420E-19 2.310E-19 2.180E-19 2.290E-19 2.270E-19 2.030E-19 2.090E-19 2.330E-19 2.330E-19 2.410E-19
etc.
  CCL3F     830.0010  859.9960      2023     233.0    0.0000  NCAR      CFC-11
 1.940E-19 1.960E-19 1.790E-19 1.710E-19 1.730E-19 1.730E-19 1.670E-19 1.670E-19 1.760E-19 1.910E-19
etc.
  CCL3F     830.0010  859.9960      2023     213.0    0.0000  NCAR      CFC-11
 1.480E-19 1.530E-19 1.520E-19 1.510E-19 1.350E-19 1.170E-19 1.170E-19 1.170E-19 1.380E-19 1.560E-19
etc.
  CCL3F     830.0010  859.9960      2023     203.0    0.0000  NCAR      CFC-11
 1.450E-19 1.390E-19 1.270E-19 1.360E-19 1.240E-19 1.070E-19 1.210E-19 1.240E-19 1.090E-19 1.110E-19
etc.
***     51          6
  CCL3F    1060.0090 1106.9890      3168     293.0    0.0000  NCAR      CFC-11
 1.430E-19 1.420E-19 1.370E-19 1.330E-19 1.340E-19 1.360E-19 1.310E-19 1.210E-19 1.230E-19 1.210E-19
etc.
  CCL3F    1060.0090 1106.9890      3168     273.0    0.0000  NCAR      CFC-11
 1.030E-19 1.040E-19 9.900E-20 9.380E-20 9.830E-20 1.060E-19 1.090E-19 1.060E-19 1.100E-19 1.060E-19
etc.
  CCL3F    1060.0090 1106.9890      3168     253.0    0.0000  NCAR      CFC-11
 9.550E-20 9.000E-20 8.260E-20 7.670E-20 8.510E-20 9.040E-20 8.440E-20 8.520E-20 9.180E-20 8.110E-20
etc.
  CCL3F    1060.0090 1106.9890      3168     233.0    0.0000  NCAR      CFC-11
 6.720E-20 6.870E-20 5.780E-20 4.900E-20 6.610E-20 7.620E-20 6.630E-20 6.350E-20 6.540E-20 5.790E-20
etc.
  CCL3F    1060.0090 1106.9890      3168     213.0    0.0000  NCAR      CFC-11
 5.610E-20 4.900E-20 4.880E-20 5.010E-20 4.420E-20 4.180E-20 5.250E-20 5.790E-20 6.250E-20 5.610E-20
etc.
  CCL3F    1060.0090 1106.9890      3168     203.0    0.0000  NCAR      CFC-11
 4.550E-20 4.730E-20 4.390E-20 4.550E-20 5.060E-20 4.710E-20 4.890E-20 4.850E-20 4.820E-20 5.170E-20
etc.
```

5. GRAPHICS AND POST-PROCESSING: PROGRAMS GENGRP AND RDOUT

5.1 Overview of the Program GENGRP

Program GENGRP performs spectral data post-processing and produces a graphics metacode file using the NCAR graphics package. The graphics are easy to understand and calls to graphics routines are confined to four of the GENGRP subroutines; PAXIS, PLTGRP, PLTBIG and TITGRP. A brief note in the code before each graphics call describes the task to be performed. This should make conversion to a different graphics package relatively painless.

GENGRP is an interactive program that prompts the user for information about the spectra to be plotted. The program reads the unformatted output file written by GENLN2. The spectra contained in this file are defined in the *OUTPUT section of the GENLN2 input file, see Section 4.10. GENGRP produces a single frame on which several curves can be plotted. The user has full control over the axis limits and labels and the curve pen color and dash pattern. Any of the spectra contained on the output file can be plotted: the high-resolution point spectra that were calculated on the fine wavenumber grid and/or the binned spectra integrated over the wide mesh intervals.

There is provision for degrading the point spectra with an instrument function. The choices here are a user supplied function, a boxcar, triangle or a cut-off of the Fourier transform of the spectrum appropriate when modelling a Fourier transform spectrometer. Four apodizing functions due to *Norton and Beer* (1976) are available with the last option. Degradation of the spectrum is performed by taking the forward fast Fourier transform (FFT), convolving the transforms of the spectrum and instrument function in Fourier space and then transforming back to wavenumber space.

There is also facility within the program for plotting other spectra, (referred to as *external*), that are read from a user supplied data file. This is useful for comparing GENLN2 spectra with other spectra, or for super-imposing a radiometer channel response function over the calculated spectra.

5.2 Description of GENGRP Subroutines

The GENGRP program structure is shown in Fig.5.1.

GENGRP - Main program. Management program for the calculation.

GRPDAT - Block data subroutine. Initializes data for GENGRP common blocks. This includes data for pen colors and dash patterns.

RDOG1 - Subroutine. Reads the first section of the GENLN2 output file, that written by GENLN2 subroutine OUTGR1. The information read here is mainly for data management.

ASKME - Subroutine. Routine for the interactive input to GENGRP. Question are written to FORTRAN unit 6. A check is made to ensure that the curve data requested for plotting is available on the GENLN2 output data file.

PAXIS - Subroutine. Graphics routine for producing the plot frame, axes and titles. NCAR GRAPHICS SPECIFIC.

ARRCHK - Subroutine. Checks that the maximum array dimensions defined in PARRAY are large enough to accommodate the GENLN2 spectral data.

RDOG2 - Subroutine. Reads the section of the GENLN2 output file written by GENLN2 subroutine OUTGR2. The information read here are path and mixed path point transmittance spectra.

PTHST - Subroutine. Creates a curve data array if a path or mixed path point transmittance spectrum is to be plotted

RDOG3 - Subroutine. Reads the section of the GENLN2 output file written by GENLN2 subroutine OUTGR3. The information read here are layer transmittance and radiance point spectra.

RADST - Subroutine. Creates a curve data array if a layer transmittance or radiance point spectrum is to be plotted.

RDOG4 - Subroutine. Reads the section of the GENLN2 output file written by GENLN2 subroutine OUTGR4. The information read here are binned spectra integrated over the wide mesh intervals.

INTST - Subroutine. Creates a curve data array if an integrated spectrum is to be plotted.

INSFCT - Subroutine. Main routine for managing the convolution of the spectra with an instrument response function

DEGUNE - Subroutine. Degrades a spectrum with either a boxcar or triangle instrument function when the spectral fine grid points are not evenly spaced. The convolution is performed via a trapezium rule integration in spectral space. This method is time consuming. If evenly spaced fine mesh points are defined for the GENLN2 calculation then the more efficient convolution in Fourier space will automatically be used.

ILSINT - Subroutine. Prepares the instrument response function (boxcar, triangle or user supplied) data array before the forward FFT is made.

ILSFFT - Subroutine. Takes the forward FFT of the instrument response function from spectral to Fourier space.

FFTRC - Subroutine. Takes forward FFT of an array.

FFT2V - Subroutine. FFT array management routine.

APODIZ - Subroutine. This routine degrades the spectrum with the instrument function of a Fourier transform spectrometer. The forward FFT of the spectrum is made, the transform is truncated according to the spectrometer resolution and the apodizing function is applied. The backward FFT is then made to obtain the degraded spectrum in wavenumber space.

FFTCR - Subroutine. Takes backward FFT of an array.

CONSPC - Subroutine. Takes the forward FFT of the spectrum and convolves it with the transform of the instrument function (boxcar, triangle or user supplied) that was created by ILSFFT. The backward FFT is then made to obtain the degraded spectrum in wavenumber space.

NORMAL - Subroutine. The maximum y-value, y_{max}, of all the spectrum curves is found. This is then used to normalize the curves to unity according to $y' = y/y_{max}$.

PLTGRP - Subroutine. If the spectral range for plotting and the point density are such that all the spectral curve data can be held in memory at one time, i.e. the total number of points is less than or equal to MXPTS in the PARRAY statement, this routine plots the spectral curves according to the chosen pen color and dash pattern. If the arrays are too large, then the routine writes the curve data to a temporary work file for later analysis in sections determined by the size of MXPTS.
NCAR GRAPHICS SPECIFIC.

PLTBIG - Subroutine. If subroutine PLTGRP used the temporary work file, this routine reads the sections of spectral data, performs any required normalization and plots the spectral curves according to the chosen pen color and dash pattern.
NCAR GRAPHICS SPECIFIC.

TITGRP - Subroutine. This routine labels the graph with titles and adds keys to identify the different spectral curves. Any external spectra that are to be plotted on the same graph as the GENLN2 spectra are plotted and labelled at this time.
NCAR GRAPHICS SPECIFIC.

5.3 Description of the GENGRP Interactive Input

GENGRP is an interactive program. During execution it prompts the user for required input. The questions asked are described below along with the different options.

```
##################################################
##################################################
##                PROGRAM GENGRP                ##
##                --------------                ##
##  GENERAL PURPOSE GRAPHICS FOR PLOTTING       ##
##  GENLN2 TRANSMITTANCE AND RADIANCE SPECTRA   ##
##  VERSION 3.0   D.P. EDWARDS   27/02/91       ##
##  (C) COPYRIGHT 1991 UCAR/NCAR                ##
##  ALL RIGHTS RESERVED                         ##
##  GENLN2 SOFTWARE AND RELATED MATERIALS MAY   ##
##  BE USED ONLY UNDER AN EXECUTED VALID        ##
##  LICENCE AGREEMENT                           ##
##################################################
##################################################
**Q** Name of GENLN2 unformatted output file to plot? :
```

Enter the file name of the GENLN2 unformatted output file.

```
**Q** Enter filename of output graphics metacode file :
```

Enter the file name of the output graphics metacode.

```
**Q** Do you want the default picture size? [Y/N] :
```

The default picture size is the largest NCAR graphics frame size available with the output device being used. If N then:

```
**Q** Enter X-axis length, Y-axis length in cm :
```

The graphics program plots a single frame but several (up to MXCUR in the PARRAY file) curves can be plotted within this frame.

```
**Q** For a default axis, the axis drawn will be
```

```
that appropriate for the first curve entered.
Is a default X-axis to be drawn? [Y/N] :
```

For Y a default X-axis scale will cover the full wavenumber range of the GENLN2 run.

```
**Q** Is a default Y-axis to be drawn? [Y/N] :
```

For Y the Y-axis scale will cover the appropriate range of values for the first curve to be specified later. If the answer is N to either of the above questions you will be prompted for limiting axis values and axis titles:

```
**Q** Enter XMIN and XMAX values for user's X axis :
**Q** Enter X axis title :
```

and/or:

```
**Q** Are normalized spectra to be plotted? [Y/N] :
```

If Y the maximum Y-value of all the spectra to be plotted y_{max}, will be used to normalize all the other spectra such that the quantity plotted is $y' = y/y_{max}$. If N then:

```
**Q** Enter YMIN and YMAX values for user's Y axis :
**Q** Enter 1 for linear scale, 2 for log scale :
```

then:

```
**Q** Enter Y axis title :
**Q** Enter graph title :
```

You will then be asked about the curves to be plotted:

```
**Q** Enter the no. of curves to be plotted on this graph? :
**Q** Do you want to supply your own curve captions? [Y/N] :
```

The next section specifies the curves to be plotted. The following questions will be repeated until all the curves to be plotted are defined.

```
##### CURVE NO. 1  #####
**Q** Is a path transmittance spectrum                    (PT),
      a mixed path transmittance spectrum                 (XT),
      a radiating atmosphere layer transmittance spectrum (AT),
      or a radiating atmosphere layer radiance spectrum   (AR)
      to be plotted?
      Enter one of PT, XT, AT or AR :
```

If you enter PT you will be asked for the path number IPATH to be plotted:

```
**Q** Curve 1. IPATH no. of path to be plotted? :
```

or if you enter XT you will be asked for the mixed path number IPMIX to be plotted:

```
**Q** Curve 1. IPMIX no. of mixed path to be plotted? :
```

or if you enter AT or AR you will be asked for the atmosphere number IATM and layer number ILAY:

```
**Q** Curve 1. IATM no. of layer atmosphere? :
**Q** Curve 1. ILAY no. of layer to be plotted? :
```

You will then be asked if you want to plot a binned spectra integrated over the wide mesh intervals or a fine wavenumber grid point spectra:

```
**Q** Are wide mesh binned spectral values to be plotted? [Y/N] :
```

You will be asked which pen and curve dash pattern are to be used to plot this curve. This will depend on the output device being used. There are eight pen colors and eight dash patterns defined in block data GRPDAT.

```
**Q** Enter line type and pen type for drawing :
```

If you said you wanted to supply your own curve captions:

```
**Q** Enter curve caption, 50 chars. max. :
```

The spectra that are written by GENLN2 to the output data file are specified in the GENLN2 input file section *OUTPUT. Obviously the spectrum selected for plotting above must be one of those written to the output file. At this stage the the program checks the output data file to ensure the spectral data for the selection is available. If it is, the program proceeds with the data input for curve 2. When input data for all NCUR curves is complete, the user will be prompted with the questions below.

If binned spectra integrated over the wide mesh intervals are not being plotted, the program will either plot the spectra at effectively infinite resolution as calculated by GENLN2 or the spectra may be degraded by an instrument line shape function.

```
**Q** Do you want to degrade the spectra with an
      instrument line shape (ILS) function? [Y/N] :
```

If Y then:

```
**Q** ILS function type specifier;
      1 = square boxcar
      2 = triangle
      3 = Fourier spec. (only with evenly spaced points)
      4 = user supplied (only with evenly spaced points)
      Enter 1,2,3 or 4 :
```

If 1 then:

```
**Q** Enter square box resolution in cm-1 :
```

or else if 2:

```
**Q** Enter triangle half power band width in cm-1 :
```

Choices 3 and 4 are only available if the GENLN2 fine wavenumber grid has a constant spacing over all wide meshes. See the description of the GENLN2 input file *SPECTM section (1C) NDIV parameter in Section 4.10. The constant spacing is required by the FFT routines that convolve the spectra and instrument function in Fourier space. If the wavenumber grid has unequal spacing choices 1 and 2 are still available but the convolution integral is performed in spectral space.

If choice 3 is selected you will be asked for the maximum optical retardation of the spectrometer and the apodization model that should be used:

```
**Q** Enter max. retardation length in cm :

**Q** Fourier apodization specifier;
      1 = no apodization
      2 = triangular apodization
      3 = Norton & Beer weak apodization
      4 = Norton & Beer medium apodization
      5 = Norton & Beer strong apodization
      Enter 1,2,3,4 or 5 :
```

or else if the choice is 4 you will be asked for the name of the file that contains the instrument response function data:

```
**Q** Enter ILS function data filename :
```

The ILS function data file follows the format used by all GENLN2 programs for reading external spectral values as a function of wavenumber. It will be referred to from here on as the External Spectra Data Arrangement (ESDA). An example instrument function data set is shown in Table 5.1 and illustrates the description given below.

Header records:
The file may have any number of title header records beginning with the ! character.

First input record:
This record contains two data labels. The first label is a five character string ('INST1' in the example), and the second label is an integer (792). Some of the GENLN2 codes that use the ESDA make use of these labels, in this case they are not used.

Second input record:
The first parameter (integer) is the number of spectral points that appear in the file (26 in this case). This value must be less than or equal to MXRPT in the PARRAY statement. The second is a number (real) to characterize the resolution of the spectral data in wavenumbers. In the instrument response file here it defines the resolution of the instrument (0.25 cm^{-1}).

Spectral point records:
There then follows a record for each of the spectral data point (26 here). The first parameter (integer) is the point number, the second is the wavenumber (real), and the third the spectral value. In this example the spectral values are the instrument function responses. Since the function will be used as a spectral filter, the starting wavenumber value is arbitrary and only the increment between wavenumber points is important.

You will then be asked to supply the point density for plotting. Plotting all points of a high resolution spectra is not always necessary and a reduced graphics metacode file plots faster on an output device.

```
**Q** Are all points to be plotted? [Y/N] :
```

If N then:

```
**Q** Enter no of plot points/cm-1 :
```

The graphics program has the facility for plotting spectral curves on this picture from data taken from an external file. Up to MXRES (in the PARRAY) file external curves, each taken from a different data file having the ESDA format described above can be plotted within this frame.

```
**Q** Is an external spectra to be plotted? [Y/N] :
```

If Y then:

```
**Q** Enter number of external spectra for plotting :

##### EXTERNAL SPECTRUM NO. 1  #####
**Q** Enter name of file containing spectrum data :
```

Enter the name of the external spectra data file in the ESDA format.

```
**Q** Enter spectrum caption, 50 chars. max. :
```

The program then continues with the data input for the other external spectra curves. Finally:

```
**Q** Enter spectrum plot Y-axis title :
```

5.4 GENGRP Implementation

The execution of the GENGRP program is performed with the following operations:

1. Program GENGRP and its subroutines are compiled and linked. The NCAR graphics library should be linked with the program at this time.

3. The program is executed. The input is via interactive prompting at the terminal.

Program GENGRP uses the PARRAY parameter file (Table 3.3) to set the maximum array dimensions.

MXCUR - Maximum number of GENLN2 spectral curves that will be plotted.

MXPTS - Maximum number of data points that will be held in memory at any one time for any one spectral curve. If the spectra are being convolved with an instrument response function, MXPTS should by a power of 2. Besides this requirement, the value will probably be dictated by machine memory limitations. A value of 8192, 16384 or 32768 should work.

MXRES - Maximum number of external spectra that will be plotted.

MXRPT - Maximum number of external spectra points in any external spectra curve.

The input/output FORTRAN unit numbers used by program GENGRP are:

Unit 5. Input
Used for reading the interactive input from the terminal.

Unit 6. Output
Used for writing interactive questions to the terminal.

Unit 10. Input
Used to read the GENLN2 unformatted output file containing the spectral data.

Unit 11. Input
Used to input the instrument response function and/or the external spectra for plotting.

Unit 30. Input/Output
Used for writing and reading the temporary spectral array storage data file.

5.5 Overview of the Program RDOUT

Program RDOUT is a skeleton routine for reading the GENLN2 unformatted output file. It is provided as a basis for users who wish to perform their own GENLN2 post-processing. Program GENGRP is itself built on the RDOUT framework. The program consists of the main program and calls to the reading routines RDOG1, RDOG2, RDOG3 and RDOG4 as described in Section 5.2. The program RDOUT is well commented and describes in detail the spectral data as they are read. This data may then be manipulated as required. It is anticipated that users will write their own input and output interface to this program.

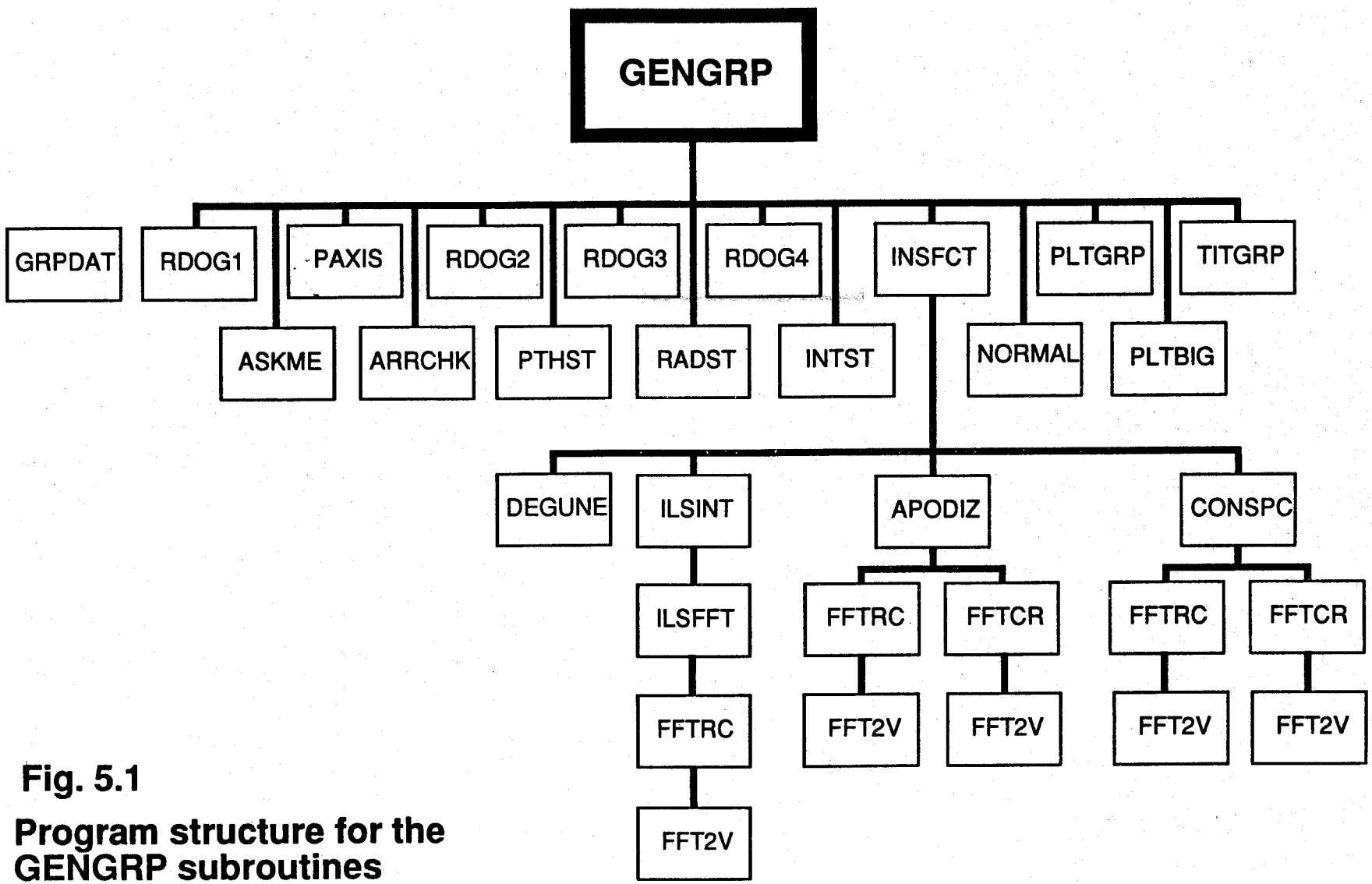


Fig. 5.1

Program structure for the GENGRP subroutines

Table 5.1 Example of the External Spectra Data Arrangement
ESDA


```
!*************************************
! EXAMPLE INSTRUMENT FUNCTION DATA FILE
! USING THE ESDA
!*************************************
! Data arrangement of spectral point records:
! Point no.,   wavenumber,    spectral value
!
'INST1',  792    ! 5 character label, integer label
26,       0.25   ! # data pts, resolution cm-1
          1     791.0000       0.000E+00
          2     791.5183       0.000E+00
          3     791.5673       0.000E+00
          4     791.6163       0.000E+00
          5     791.6654       1.000E+00
          6     791.7144       4.000E+00
          7     791.7635       7.000E+00
          8     791.8125       1.100E+01
          9     791.8615       1.800E+01
         10     791.9106       3.100E+01
         11     791.9596       5.100E+01
         12     792.0087       7.700E+01
         13     792.0577       8.800E+01
         14     792.1067       6.600E+01
         15     792.1558       3.600E+01
         16     792.2048       2.300E+01
         17     792.2538       1.400E+01
         18     792.3029       8.000E+00
         19     792.3519       5.000E+00
         20     792.4010       3.000E+00
         21     792.4500       1.000E+00
         22     792.4990       5.000E-01
         23     792.5481       0.000E+00
         24     792.5971       0.000E+00
         25     792.6462       0.000E+00
         26     793.0000       0.000E+00
```

6. CALCULATIONS WITH A RADIOMETER: PROGRAMS BRIGHT AND RADTEM

6.1 Overview of Programs BRIGHT and RADTEM

The program BRIGHT was originally written for application in satellite meteorology where the simulation of the signal detected by a wide-band radiometer is required. The basic function of the code is to convolve the high-resolution GENLN2 spectra with the radiometer channel response function.

The calculation may be performed in two ways and the choice will depend on the resolution of the radiometer. If the channel covers only a few wavenumbers then the response function is likely to be changing significantly over the interval of the GENLN2 wide mesh spacing. In this case the monochromatic spectra $R(\nu)$ (transmittance or radiance for some path, mixed path or layer), calculated on the fine wavenumber grid should be convolved with the channel response function $f(\nu)$. If the channel width, $\Delta\nu$ wavenumbers, covers N wide mesh intervals i each of width $\delta\nu_i$ wavenumbers such that

$$\Delta\nu = \sum_{i=1}^{N} \delta\nu_i,$$

then the calculation takes the form

$$\overline{R}_{\Delta\nu} = \frac{\sum_{i=1}^{N} \int_{\delta\nu_i} R(\nu) f(\nu) d\nu}{\sum_{i=1}^{N} \int_{\delta\nu_i} f(\nu) d\nu}, \tag{6.1}$$

to give the channel convolved signal $\overline{R}_{\Delta\nu}$. Alternatively, if the channel is wide, greater than 20 cm^{-1}say, the response function can be convolved with the binned spectra that have been integrated over the wide mesh intervals in GENLN2. The advantage of this approach is that the calculation is quicker. Also, since the binned spectra and not the fine grid spectra are output from GENLN2, it can significantly reduce computer storage if the spectra of many GENLN2 calculations are saved for convolution with channel response functions at a later time. In this case $\overline{R}_{\Delta\nu}$ is calculated as

$$\overline{R}_{\Delta\nu} = \frac{\sum_{i=1}^{N} R_{\delta\nu_i} f_{\delta\nu_i}}{\sum_{i=1}^{N} f_{\delta\nu_i}}, \tag{6.2}$$

where

$$f_{\delta\nu_i} = \int_{\delta\nu} f(\nu) d\nu \tag{6.3}$$

and $R_{\delta\nu_i}$ is the GENLN2 binned spectral value. The choice of calculation scheme should be made before the GENLN2 run so that the required spectra can be output.

It is often useful to convert a channel radiance $\overline{I}_{\Delta\nu}$ into an *equivalent brightness temperature*, T_{eqv}. This is defined by the equation

$$\overline{I}_{\Delta\nu} = \frac{\int_{\Delta\nu} B(\nu, T_{eqv})\, f(\nu) d\nu}{\int_{\Delta\nu} f(\nu) d\nu} \tag{6.4}$$

where $B(\nu, T_{eqv})$ is the Planck function. Program BRIGHT allows for an equivalent brightness temperature to be assigned to a channel radiance once a look-up table for converting radiance to brightness temperature has been made. This is done using the program RADTEM.

6.2 Description of BRIGHT and RADTEM Subroutines

The BRIGHT and RADTEM program structure is shown in Fig.6.1.

BRIGHT - Main program. Management program for the calculation.

RDINT - Subroutine. Reads the GENLN2 output file and returns the binned average wide mesh transmittances and radiances.

RDOG1 - Subroutine. Reads the first section of the GENLN2 output file, that written by GENLN2 subroutine OUTGR1. The information read here is mainly for data management.

RDOG2 - Subroutine. Reads the section of the GENLN2 output file written by GENLN2 subroutine OUTGR2. The information read here are path and mixed path point transmittance spectra.

RDOG3 - Subroutine. Reads the section of the GENLN2 output file written by GENLN2 subroutine OUTGR3. The information read here are layer transmittance and radiance point spectra.

RDOG4 - Subroutine. Reads the section of the GENLN2 output file written by GENLN2 subroutine OUTGR4. The information read here are binned spectra integrated over the wide mesh intervals.

FILTER - Subroutine. Calculates the integral of the radiometer channel response function over the GENLN2 wide mesh, $f_{\delta\nu_i}$ in Eqn.(6.3).

INTEG - Subroutine. General purpose numerical routine to calculate a weighted integration using Simpson's rule.

INTER - Subroutine. General purpose numerical interpolation routine for interpolating between two arrays at a supplied argument value. Several interpolation options are available.

RDPTS - Subroutine. Reads the GENLN2 output file. The transmittance and radiance spectra calculated on the fine wavenumber grid are convolved with the radiometer response function. The convolved spectra binned over the wide mesh, the upper integral in Eqn.(6.1), is returned.

TRINTG - Subroutine. General purpose integration routine using the trapezium rule. Used to integrate the radiometer response function, path, mixed path and layer transmittances and radiance over each wide mesh interval.

CONVOL - Subroutine. Performs the convolutions represented by the sums of Eqns.(6.1) and (6.2).

BRTEMP - Subroutine. Converts convolved radiances to equivalent brightness temperature with the aid of the look-up table produced by program RADTEM.

BRIOUT - Subroutine. Output routine for writing the channel response convolved transmittances, radiances and equivalent brightness temperatures.

RADTEM - Main program. Computes the radiance to equivalent brightness temperature look-up table for a given radiometer channel response function.

6.3 Description of the BRIGHT Interactive Input

BRIGHT is an interactive program. During execution it prompts the user for required input. The questions asked are described below along with the different options.

```
##################################################
##################################################
##            PROGRAM BRIGHT                    ##
##            --------------                    ##
##   POST-PROCESSING PROGRAM FOR GENLN2:        ##
##   CONVOLVES TRANSMITTANCES/RADIANCES WITH    ##
##   A RADIOMETER WIDEBAND RESPONSE FUNCTION    ##
##   AND OPTIONALLY CONVERTS TO EQUIVALENT      ##
##   BRIGHTNESS TEMPERATURE                     ##
##   VERSION 3.0   D.P. EDWARDS   27/02/91      ##
##   (C) COPYRIGHT 1991 UCAR/NCAR               ##
##   ALL RIGHTS RESERVED                        ##
##   GENLN2 SOFTWARE AND RELATED MATERIALS MAY  ##
##   BE USED ONLY UNDER AN EXECUTED VALID       ##
##   LICENCE AGREEMENT                          ##
##################################################
##################################################
**Q** Enter name of GENLN2 unformatted output file :
```

Enter the file name of the GENLN2 unformatted output file. You will then be asked if you want to convolve the binned spectra integrated over the wide mesh as in Eqn.(6.2) or use the fine wavenumber grid point spectra as in Eqn.(6.1):

```
**Q** Are wide mesh binned spectral values to be used? [Y/N] :
```

Then give the name of the file containing the radiometer channel response data, $f(\nu)$. This file should be arranged in the ESDA format, Section 5.3.

```
**Q** Enter name of channel response data file :
```

You will be asked to specify which spectra (if present on the GENLN2 output file) are to be convolved:

```
**Q** Are path transmittances to be convolved? [Y/N] :
**Q** Are mixed path transmittances to be convolved? [Y/N] :
**Q** Are layer transmittances to be convolved? [Y/N] :
**Q** Are layer radiances to be convolved? [Y/N] :
```

If the radiances are to be convolved there is the option to convert to equivalent brightness temperature. The radiance to brightness temperature look-up table must previously have been calculated using program RADTEM.

```
**Q** Are brightness temps to be calculated?  [Y/N] :
**Q** Enter name of rad.--> bright.T. look-up file :
```

Finally, you will be asked for the name of the output file:

```
**Q** Enter name of output file :
```

6.4 BRIGHT Implementation

The execution of the BRIGHT program is performed with the following operations:

1. Program BRIGHT and its subroutines are compiled and linked.

3. The program is executed. The input is via interactive prompting at the terminal.

Program BRIGHT uses the PARRAY parameter file (Table 3.3) to set the maximum array dimensions. The PARRAY file used should be that used by the corresponding GENLN2 calculation.

The input/output FORTRAN unit numbers used by program BRIGHT are:

Unit 5. Input
Used for reading the interactive input from the terminal.

Unit 6. Output
Used for writing interactive questions to the terminal.

Unit 10. Input
Used to read the GENLN2 unformatted output file containing the spectral data.

Unit 11. Input
Used to input the radiometer channel response function.

Unit 12. Input
Used to input the radiometer channel radiance to equivalent brightness temperature conversion look-up table.

Unit 30. Output
Used for writing the BRIGHT output data file.

6.5 Description of the RADTEM Interactive Input

RADTEM is also an interactive program. During execution it prompts the user for required input. The questions asked are described below along with the different options.

```
##############################################
##############################################
##            PROGRAM RADTEM                ##
##            --------------                ##
##  PROGRAM TO CALCULATE A RADIANCE TO      ##
##  EQUIVALENT BRIGHTNESS TEMPERATURE       ##
##  LOOK-UP TABLE FOR A GIVEN RADIOMETER    ##
##  WIDEBAND RESPONSE FUNCTION.             ##
##  VERSION 3.0   D.P. EDWARDS   27/02/91   ##
##  (C) COPYRIGHT 1991 UCAR/NCAR            ##
##  ALL RIGHTS RESERVED                     ##
##  GENLN2 SOFTWARE AND RELATED MATERIALS   ##
##  MAY BE USED ONLY UNDER AN EXECUTED      ##
##  VALID LICENCE AGREEMENT                 ##
##############################################
##############################################
**Q** Enter name of channel response data file :
```

Give the name of the file containing the radiometer channel response data $f(\nu)$. This file should be arranged in the ESDA format, Section 5.3.

```
**Q** Enter name of rad.--> bright.T. output look-up file :
```

Give the name of the output look-up file for the conversion of radiance to equivalent brightness temperature. This is the file used by BRIGHT.

```
**Q** Enter the lower and upper temperatures [K] and
      no of temperature points per degree K:
```

Give the lower and upper temperatures in K for the look-up table. For the Earths atmosphere the range should be somewhere between 150 and 350 K. The number of temperature points for calculation will determine how accurate the conversion from radiance to equivalent brightness temperature is. If the number of temperature points is 10 then the temperature step in the look-up table will be 0.1 K. Program BRIGHT performs a linear interpolation of the convolved radiance between the radiances of consecutive temperatures separated by one step in the look-up table.

```
**Q** Enter number of points for spectral integration  :
```

The convolution represented in Eqn.(6.4) is performed using a trapezium rule integration with the specified number of points over the width $\Delta\nu$ wavenumbers of the radiometer channel response. An example of the look-up table is shown in Table 6.1.

6.6 RADTEM Implementation

The execution of the RADTEM program is performed with the following operations:

1. Program RADTEM and its subroutines are compiled and linked.

3. The program is executed. The input is via interactive prompting at the terminal.

Program RADTEM uses the PARRAY parameter file.

The input/output FORTRAN unit numbers used by program BRIGHT are:

Unit 5. Input
Used for reading the interactive input from the terminal.

Unit 6. Output
Used for writing interactive questions to the terminal.

Unit 10. Input
Used to input the radiometer channel response function.

Unit 30. Output
Used to output the radiometer channel radiance to equivalent brightness temperature conversion look-up table.

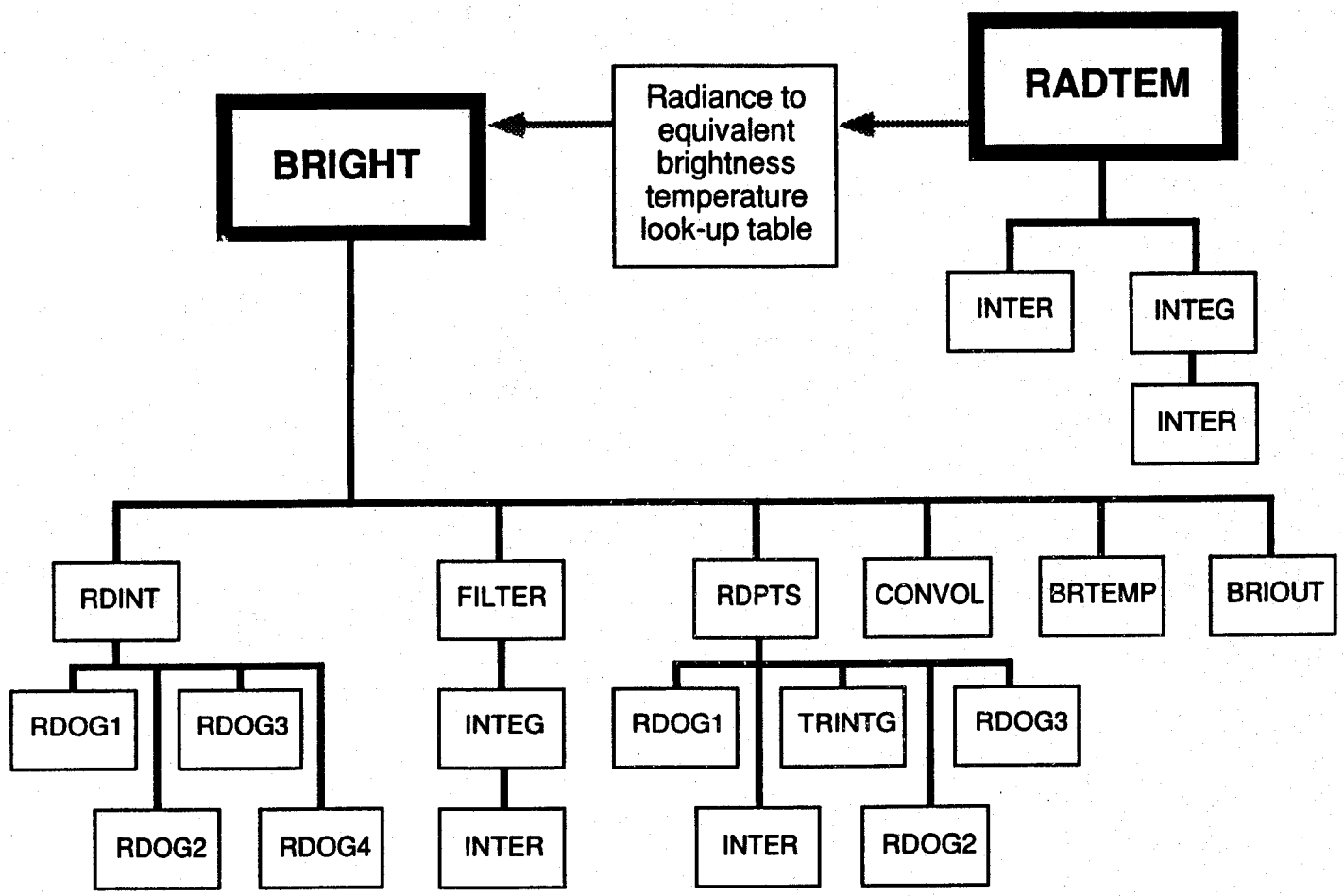


Fig. 6.1

Program structure for the BRIGHT and RADTEM subroutines

Table 6.1 Example of radiance to brightness temperature look-up file
RADTEM


```
! ***********************************************
! ***********************************************
! **  RADTEM: POST-PROCESSING PROGRAM FOR       **
! **  GENLN2. RADIANCE-->EQUIVALENT BRIGHTNESS  **
! **  TEMPERATURE ([W/(m2.sr.cm-1)]-->[K])      **
! **  CONVERSION LOOKUP TABLE                   **
! **  VERSION 3.0   D.P. EDWARDS   27/02/91     **
! **  (C) COPYRIGHT 1991 UCAR/NCAR              **
! **  ALL RIGHTS RESERVED                       **
! **  GENLN2 SOFTWARE AND RELATED MATERIALS     **
! **  MAY BE USED ONLY UNDER AN EXECUTED VALID  **
! **  LICENCE AGREEMENT                         **
! ***********************************************
! ***********************************************
!
! RADIANCE AT TEMPERATURES BETWEEN 150.0 AND 350.0 K IN  0.100 K INTERVALS
! FILTER PROFILE TAKEN FROM:-
! ****************************************************
! *  RADIOMETER RESPONSE PROFILE FOR INST2, CHANNEL 3 *
! ****************************************************
! DATA FOR CHANNEL NO.  3
! FREQUENCY MESH FOR PLANCK FUNCTION CONVOLUTION  0.500 cm-1.
!
  150.0    350.0      10
  150.000    1.299519E-03 1.307230E-03 1.314974E-03 1.322756E-03 1.330572E-03
             1.338425E-03 1.346314E-03 1.354237E-03 1.362198E-03 1.370194E-03
  151.000    1.378227E-03 1.386297E-03 1.394402E-03 1.402545E-03 1.410724E-03
             1.418940E-03 1.427193E-03 1.435483E-03 1.443811E-03 1.452174E-03
  152.000    1.460577E-03 1.469017E-03 1.477493E-03 1.486008E-03 1.494560E-03
             1.503151E-03 1.511780E-03 1.520447E-03 1.529152E-03 1.537895E-03
  153.000    1.546678E-03 1.555498E-03 1.564357E-03 1.573256E-03 1.582192E-03
             1.591169E-03 1.600184E-03 1.609239E-03 1.618334E-03 1.627466E-03
  154.000    1.636640E-03 1.645854E-03 1.655105E-03 1.664399E-03 1.673731E-03
             1.683105E-03 1.692519E-03 1.701972E-03 1.711467E-03 1.721002E-03
  155.000    1.730577E-03 1.740195E-03 1.749851E-03 1.759550E-03 1.769290E-03
             1.779071E-03 1.788895E-03 1.798759E-03 1.808665E-03 1.818612E-03
  156.000    1.828603E-03 1.838634E-03 1.848707E-03 1.858824E-03 1.868982E-03
             1.879184E-03 1.889428E-03 1.899714E-03 1.910042E-03 1.920414E-03
  157.000    1.930829E-03 1.941288E-03 1.951789E-03 1.962334E-03 1.972923E-03
             1.983554E-03 1.994231E-03 2.004950E-03 2.015714E-03 2.026521E-03
  158.000    2.037374E-03 2.048272E-03 2.059210E-03 2.070197E-03 2.081225E-03
             2.092301E-03 2.103422E-03 2.114585E-03 2.125796E-03 2.137049E-03
  159.000    2.148350E-03 2.159697E-03 2.171088E-03 2.182526E-03 2.194008E-03
             2.205537E-03 2.217114E-03 2.228734E-03 2.240402E-03 2.252116E-03
  160.000    2.263877E-03 2.275685E-03 2.287538E-03 2.299440E-03 2.311387E-03
             2.323383E-03 2.335426E-03 2.347515E-03 2.359652E-03 2.371837E-03
  161.000    2.384070E-03 2.396351E-03 2.408678E-03 2.421057E-03 2.433479E-03
             2.445953E-03 2.458478E-03 2.471045E-03 2.483664E-03 2.496330E-03
  162.000    2.509048E-03 2.521815E-03 2.534628E-03 2.547493E-03 2.560406E-03
             2.573368E-03 2.586382E-03 2.599442E-03 2.612556E-03 2.625716E-03
  163.000    2.638930E-03 2.652193E-03 2.665503E-03 2.678868E-03 2.692281E-03
             2.705747E-03 2.719263E-03 2.732828E-03 2.746446E-03 2.760112E-03
  164.000    2.773834E-03 2.787606E-03 2.801427E-03 2.815303E-03 2.829228E-03
             2.843206E-03 2.857239E-03 2.871318E-03 2.885454E-03 2.899640E-03
  165.000    2.913881E-03 2.928172E-03 2.942517E-03 2.956914E-03 2.971362E-03
             2.985868E-03 3.000426E-03 3.015035E-03 3.029699E-03 3.044415E-03
etc
```

APPENDIX 1. EXAMPLE CALCULATION 1: NADIR VIEW

A1.1 Overview of Example Calculation 1

Example calculation 1 is for a nadir viewing geometry problem from satellite meteorology. The object is to calculate the observed brightness temperature of the Advanced Very High Resolution Radiometer (AVHRR) in channel number 4 of the 10 μm window (*Saunders and Edwards*, 1989). Three parallel radiance calculations are performed. The first assumes a clear sky view of the sea surface, the second and third calculate the radiance from cloud tops at 5 and 10 km. In addition, transmittance calculations are performed to find the transmittance of the total atmosphere due to the different gases, including CFC12, that are important in this spectral region.

This calculation uses all the programs of the GENLN2 suite. The reader is referred to the input and output listings and the main text. As some of the output files are large, only a summary is given here. The full files are included on the GENLN2 tape. The PARRAY file used for the calculations is that shown in Table 3.3.

Both the example calculation given here were run on an IBM RS6000/530 under UNIX and a XLF compiler.

A1.2 Program HITLIN

This calculation assumes that a line data file for use with GENLN2 is not already available. Only one input line data file in the HITRAN format is used, the March 1991 HITRAN general release, and all the lines from this file are given status 10. For an accurate comparison, users wishing to run these examples should also use this version of HITRAN. The output file contains lines over the spectral range 800 to 1050 cm^{-1} only. A binary line data file **ex1_hitlin_op.dat** for use by GENLN2 is created, with MACH=2 since the calculation is performed on an the IBM. The input file **ex1_hitlin_ip.dat** should be assigned to FORTRAN unit 4 before execution.

A1.3 Program LAYERS

The LAYERS calculation layers the atmosphere using the mid-latitude summer profile data set **ex1_layers_pro.dat** supplied by the user in the *USEPRO option. The mid-latitude summer model profile (MONO=2) on the model atmosphere profile data set **glatm.dat** is also provided in case data for the calculation is required which is not available on the users profile (in this example the profile **ex1_layers_pro.dat** contains all necessary data). An integration sub-layer accuracy of 10 is specified and since this is a nadir viewing problem, the refraction calculation is switched off. The lower and upper wavenumbers of the proposed calculation range are provided for use in the calculation of the Doppler line half width in the layering calculation.

The default layering option is used with the conditions that the fractional variation in Voigt half width across a layer is not greater than 2.0 and that the layer temperature steps are not greater than 5 and 30 K for the lowest and highest layers respectively. Four gases, H_2O, CO_2, O_3 and CFC12 are included in each layer. The CO_2 line shape is specified for use with CO_2 in the GENLN2 calculation. H_2O and O_3 will use the Voigt line shape, and since line data is not available for CFC12, cross-section data will be used. Continuum absorption will be included for H_2O and CO_2. The lower and upper boundaries of the atmosphere are set at 0 km and 80 km respectively. The initial zenith angle at the bottom of the atmosphere is 0° for the vertical ray path of a nadir view.

The input file **ex1_layers_ip.dat** and the output path data file **ex1_layers_op.dat** should be assigned to FORTRAN units 4 and 30 respectively before execution.

This calculation produces a 24 layer atmosphere with each layer containing 4 gases, Fig.A1.1. There are 96 paths in total, paths 1–24 are for H_2O in layers 1–24, paths 25–48 are for CO_2 in layers 1–24, etc. The output file, **ex1_layers_op.dat**, is used as the input to the *PTHFIL input stage of GENLN2.

A1.4 Program GENLN2

The line data file produced by HITLIN, **ex1_hitlin_op.dat**, is used when performing the line-by-line calculation for H_2O, CO_2 and O_3. The cross-section data file **xsec.dat** is used for CFC12.

A default, *DEFGRD, wavenumber grid is used and 25 cm^{-1} are allowed for line wings either side of the pass-band range of 850–1000 cm^{-1}. The wide mesh interval DELTA is set at 1 cm^{-1}. In the *SPECTM section FEXC=1 cm^{-1}, and because a continuum calculation will be included FWIND=25 cm^{-1}. NDIV=500 will result in a fine wavenumber grid spacing of 0.002 cm^{-1}.

The path data is read in the *PTHFIL input section from the output file of LAYERS, **ex1_layers_op.dat**. The mixing table defines 28 mixed paths as shown in Fig.A1.1. The first 24 combine the paths of the individual gases for layers 1–24. For example, mixed path 1 is made up of path 1 (H_2O in layer 1), path 25 (CO_2 in layer 1), path 49 (O_3 in layer 1) and path 73 (CFC12 in layer 1). Mixed paths 1–24 will be used in the radiance calculations to define the total optical depth due to all gases for each layer of the atmosphere. Mixed path 25 combines all the H_2O paths from the bottom to the top of the atmosphere, mixed path 26 does the same for CO_2, 27 for O_3, and 28 for CFC12.

Three radiating atmosphere calculations are performed. The viewing parameter IVIEW=2 defines nadir views and the layer emission parameter IEMS=1 signifies that emission calculations are not being performed. All 3 atmospheres define the optical depth of the layers in terms of mixed path numbers, LAYSP=2. The first radiating atmosphere calculation assumes a clear sky view of the sea surface at 293.2 K and emittance in this spectral range of 0.9889. The temperature of the effective top of the atmosphere is assumed to be 2.96 K. There are 24 layers through which the radiation must travel between sea and satellite and the corresponding mixed path numbers of these are listed in the direction of radiation travel. The second radiating atmosphere assumes a view of a cloud top at 265 K at a height of 4.9 km, i.e. layer 1 of this calculation is defined by mixed path 6. In this case there are a total of 19 layers for the radiation to pass through defined by mixed paths 6 through 24. The third atmosphere is similar, with a cloud top at 230 K at a height of 10.4 km, i.e. layer 1 of this calculation is defined by mixed path 12. There are a total of 13 layers for the radiation to pass through defined by mixed paths 12 through 24.

The *INTEGN section is included so the spectra will be binned and averaged over the width of the wide mesh intervals. Selection of the spectra to be output is made in in the *OUTPUT section. The mixed path fine wavenumber grid point spectra for the total atmospheric transmittance of each gas, IDAT=3 mixed paths 25–28 are selected. Also sected are the point transmittance IDAT=5, and radiance spectra IDAT=7, at the top layer for each of the radiating atmosphere calculations. For the first atmosphere, the final layer of the calculation is number 24, for the second atmosphere it is 19, and for the third 12. The integrated radiance spectra, IDAT=8, are also output for these layers.

A listing is given of the formatted summary output data file. This gives a summary of the GENLN2 input to the calculation together with any integrated spectra specified for

output in *TITLES. The input file **ex1_genln2_ip.dat** and the formatted summary output data file **ex1_genln2_opd.dat** should be assigned to FORTRAN units 4 and 30 respectively before execution.

A1.5 Program GENGRP

The input dialogues and plots for three runs of GENGRP are listed. The first plot, **ex1_gengrp_trans.dat**, is of the total transmittance of the atmosphere to the four gases H_2O, CO_2, O_3, and CFC12 considered. The spectra are degraded using a triangular scanning filter with a half power band width of 0.5 cm^{-1}. The AVHRR channel 4 response function, **ex1_gengrp_res.dat**, is also plotted on this graph. This is read as an external file having the ESDA data arrangement.

The second plot, **ex1_gengrp_cfc12.dat**, is an enlargement of part of the first plot to show in detail the CFC12 absorption band and to demonstrate changing plot axis.

The third plot, **ex1_gengrp_rad.dat**, shows the radiance at the top of the atmosphere for the three cases considered here: the sea surface view and the cloud top views at 4.9 and 10.4 km. The AVHRR channel 4 response function is plotted again.

A1.6 Programs RADTEM and BRIGHT

The final part of the calculation is to convolve each radiance spectra with the AVHRR channel 4 response function, **ex1_gengrp_res.dat**, to find the channel signal and to convert this signal to equivalent brightness temperature. In order to perform the conversion, a radiance to equivalent brightness temperature look-up table, **ex1_radtem_op.dat**, must first be calculated using program RADTEM as shown in **ex1_radtem_ip.dat**.

Program BRIGHT can then be used together with the response function data and the look-up table to perform the spectral convolution. The output, **ex1_bright_op.dat**, lists the convolved radiances and equivalent brightness temperatures by radiating atmosphere calculation and layer, layer 24 being the top of the atmosphere for the first calculation, layers 19 and 12 being the top for the second and third calculations respectively.

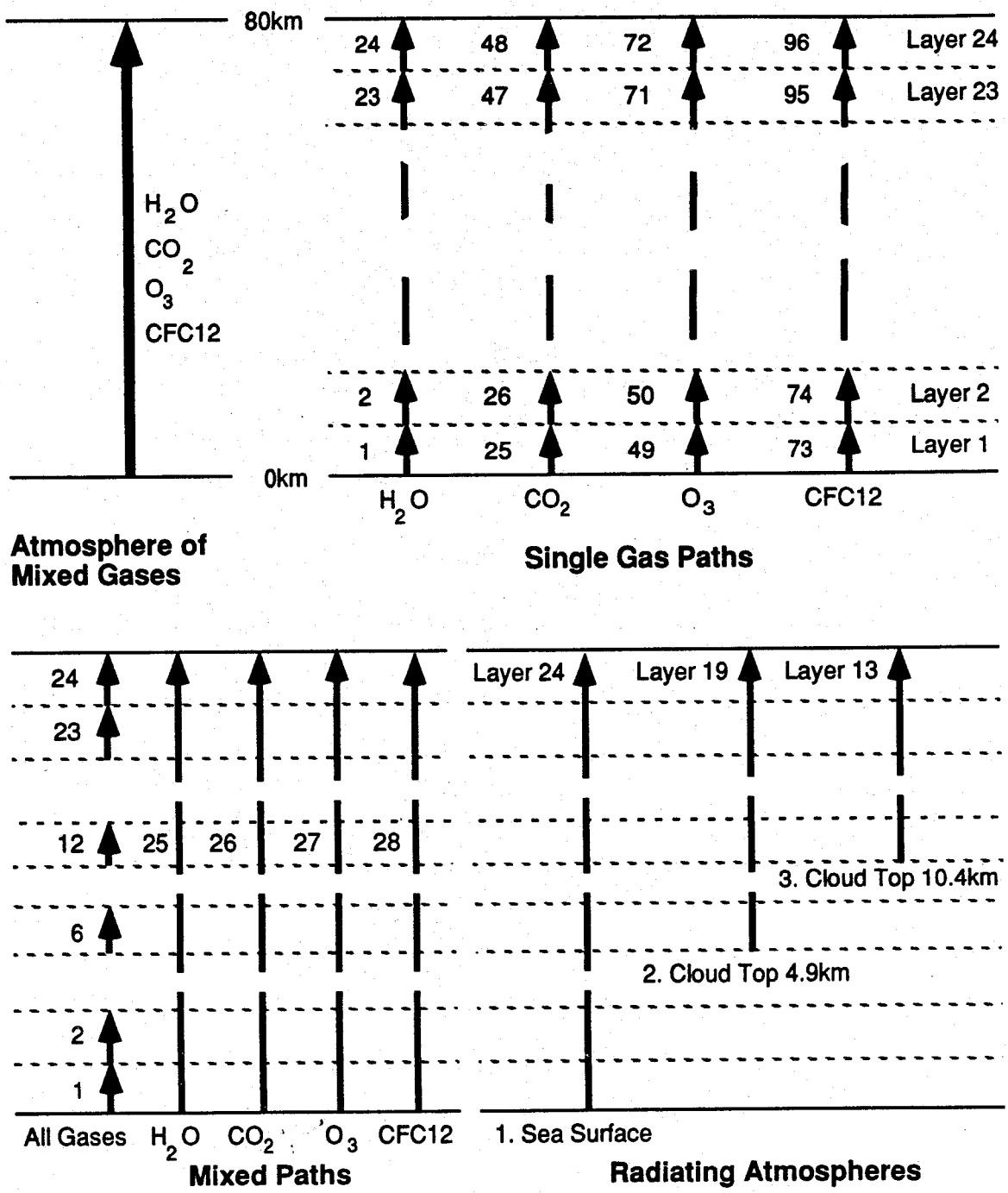


Fig. A1.1

Paths, Mixed Paths and Radiating Atmospheres for the Nadir View of Example Calculation 1.

```
!
!
!            ***********************************************
!            *                                             *
!            *          PROGRAM HITLIN: INPUT FILE         *
!            *          --------------------------         *
!            *  PROGRAM TO CREATE A BINARY LINE DATA BASE  *
!            *  FROM ONE OR MORE LINE DATA FILES IN THE    *
!            *  HITRAN FORMAT. THE BINARY FILE IS IN THE   *
!            *  REQUIRED FORM FOR GENLN2.                  *
!            *  VERSION 3.0:  D.P. EDWARDS 26/03/90        *
!            *                                             *
!            ***********************************************
!                                                    INPUT PARAMETER NAME
!-------------------------------------------------------------------------
!..TITLE LABEL FOR THIS HITLIN RUN (*TITLES) [MANDATORY]
*TITLES
!
!  1A. Title label of this HITLIN run :                              AHEAD
'Nadir example calculation: AVHRR Ch.4'
!!!!!!!! End of section !!!!!!!
!-------------------------------------------------------------------------
!..LINE DATA FILES (*LINDAT) [MANDATORY]
*LINDAT
!
!  1A. No of formatted line data files (HITRAN format)                NFIL
1
!
!  For each line data file, 1 record (IFIL=1,NFIL)
!  2A. Status number for lines on file IFIL:                     NEWST(IFIL)
!  2B. Filename of line data file:                                FNIN(IFIL)
10, 'hitran91.asc'
!!!!!!!! End of section !!!!!!!
!-------------------------------------------------------------------------
!..FREQUENCY RANGE FOR OUTPUT (*RANGES) [MANDATORY]
*RANGES
!
!  1A. Maximum number of different gases on output file:              NGAS
!  1B. Lowest wavenumber for output file:                              WN1
!  1C. Highest wavenumber for output file:                             WN2
35, 800.0, 1050.0
!!!!!!!! End of section !!!!!!!
!-------------------------------------------------------------------------
!..OUTPUT FILE (*OUTPUT) [MANDATORY]
*OUTPUT
!
!  1.A File name of the binary output line file to be used by GENLN2:  FNOUT
'ex1_hitlin_op.dat'
!
!  2.A Machine specifier, determines record length:
!      MACH=1: 4 byte/word machine, OPEN RECL in words (eg. VAX, ANSII stand)
!      MACH=2: 4 byte/word machine, OPEN RECL in bytes (eg. IBM RISC)
!      MACH=3: 8 byte/word machine, OPEN RECL in bytes (eg. CRAY)
2
!!!!!!!! End of section !!!!!!!
!-------------------------------------------------------------------------
!..END OF HITLIN INPUT (*ENDINP) [MANDATORY]
*ENDINP
!!!!!!!! End of section !!!!!!!
```

```
!
!
!*****************************************************************
!  ATMOSPHERIC PROFILE FOR MIDLATITUDE SUMMER:
!  GASES IMPORTANT FOR AVHRR CHANNEL 4.
!*****************************************************************
! Data arrangement:
! Altitude (km), Pressure (mb), Temperature (K), Total Density (molecules/cm3)
! Gas mixing ratios for listed gases (ppmv)
!
'H'  39     4                          ! Profile pts by height, # pts, # gases
1     2     3     52                   ! Gas ID's:   H2O, CO2, O3, CFC12
45.0  0.0                              ! Latitude, height of 1st pt.
   0.00 1.013E+03 294.2 2.496E+19 1.88E+04 3.30E+02 3.02E-02 5.57E-04
   1.00 9.020E+02 289.7 2.257E+19 1.38E+04 3.30E+02 3.34E-02 5.57E-04
   2.00 8.020E+02 285.2 2.038E+19 9.68E+03 3.30E+02 3.69E-02 5.57E-04
   3.00 7.100E+02 279.2 1.843E+19 5.98E+03 3.30E+02 4.22E-02 5.57E-04
   4.00 6.280E+02 273.2 1.666E+19 3.81E+03 3.30E+02 4.82E-02 5.57E-04
   5.00 5.540E+02 267.2 1.503E+19 2.23E+03 3.30E+02 5.51E-02 5.57E-04
   6.00 4.870E+02 261.2 1.351E+19 1.51E+03 3.30E+02 6.41E-02 5.57E-04
   7.00 4.260E+02 254.7 1.212E+19 1.02E+03 3.30E+02 7.76E-02 5.56E-04
   8.00 3.720E+02 248.2 1.086E+19 6.46E+02 3.30E+02 9.13E-02 5.56E-04
   9.00 3.240E+02 241.7 9.716E+18 4.13E+02 3.30E+02 1.11E-01 5.56E-04
  10.00 2.810E+02 235.3 8.656E+18 2.47E+02 3.30E+02 1.30E-01 5.56E-04
  11.00 2.430E+02 228.8 7.698E+18 9.56E+01 3.30E+02 1.79E-01 5.55E-04
  12.00 2.090E+02 222.3 6.814E+18 2.94E+01 3.30E+02 2.23E-01 5.55E-04
  13.00 1.790E+02 215.8 6.012E+18 8.00E+00 3.30E+02 3.00E-01 5.55E-04
  14.00 1.530E+02 215.7 5.141E+18 5.00E+00 3.30E+02 4.40E-01 5.54E-04
  15.00 1.300E+02 215.7 4.368E+18 3.40E+00 3.30E+02 5.00E-01 5.54E-04
  16.00 1.110E+02 215.7 3.730E+18 3.30E+00 3.30E+02 6.00E-01 5.53E-04
  17.00 9.500E+01 215.7 3.192E+18 3.20E+00 3.30E+02 7.00E-01 5.52E-04
  18.00 8.120E+01 216.8 2.715E+18 3.15E+00 3.30E+02 1.00E+00 5.51E-04
  19.00 6.950E+01 217.9 2.312E+18 3.20E+00 3.30E+02 1.50E+00 5.49E-04
  20.00 5.950E+01 219.2 1.967E+18 3.30E+00 3.30E+02 2.00E+00 5.47E-04
  21.00 5.100E+01 220.4 1.677E+18 3.45E+00 3.30E+02 2.40E+00 5.45E-04
  22.00 4.370E+01 221.6 1.429E+18 3.60E+00 3.30E+02 2.90E+00 5.42E-04
  23.00 3.760E+01 222.8 1.223E+18 3.85E+00 3.30E+02 3.40E+00 5.37E-04
  24.00 3.220E+01 223.9 1.042E+18 4.00E+00 3.30E+02 4.00E+00 5.32E-04
  25.00 2.770E+01 225.1 8.919E+17 4.20E+00 3.30E+02 4.80E+00 5.25E-04
  27.50 1.907E+01 228.4 6.050E+17 4.45E+00 3.30E+02 6.00E+00 4.92E-04
  30.00 1.320E+01 233.7 4.094E+17 4.70E+00 3.30E+02 7.00E+00 4.49E-04
  32.50 9.300E+00 239.0 2.820E+17 4.85E+00 3.30E+02 8.10E+00 3.09E-04
  35.00 6.520E+00 245.2 1.927E+17 4.95E+00 3.30E+02 8.90E+00 1.61E-04
  37.50 4.640E+00 251.3 1.338E+17 5.00E+00 3.30E+02 8.70E+00 3.83E-05
  40.00 3.330E+00 257.5 9.373E+16 5.10E+00 3.30E+02 7.55E+00 8.69E-06
  42.50 2.410E+00 263.7 6.624E+16 5.30E+00 3.30E+02 5.90E+00 9.13E-07
  45.00 1.760E+00 269.9 4.726E+16 5.45E+00 3.30E+02 4.50E+00 2.49E-07
  50.00 9.510E-01 275.7 2.500E+16 5.50E+00 3.30E+02 2.80E+00 1.00E-07
  55.00 5.150E-01 269.3 1.386E+16 5.35E+00 3.30E+00 1.80E+00 1.00E-10
  60.00 2.720E-01 257.1 7.668E+15 5.00E+00 3.30E+02 1.30E+00 1.00E-14
  70.00 6.700E-02 218.1 2.227E+15 3.70E+00 3.30E+02 4.00E-01 1.00E-18
  90.00 1.640E-03 165.0 7.204E+13 8.50E-01 3.10E+02 7.50E-01 1.00E-18
```

Ex.1. Nadir View: Program LAYERS
ex1_layers_ip.dat


```
!
!
!          ***********************************************
!          *                                             *
!          *            PROGRAM LAYERS: INPUT FILE       *
!          *            --------------------------       *
!          *  GENLN2 PATH PRE-PROCESSING PROGRAM. PERFORMS *
!          *  ATMOSPHERIC LAYERING AND CALCULATES CURTIS   *
!          *  --GODSON ABSORBER WEIGHTED MEAN PATH         *
!          *  PARAMETERS. OUTPUT PATH FILE IS IN THE FORMAT *
!          *  REQUIRED FOR DIRECT INPUT TO GENLN2.         *
!          *  VERSION 3.0: D.P. EDWARDS 01/08/90           *
!          *                                             *
!          ***********************************************
!                                                INPUT PARAMETER NAME
!-----------------------------------------------------------------------
!..TITLE INFORMATION FOR THIS LAYERS RUN (*TITLES) [MANDATORY]
*TITLES
!
!  1A. Title of this LAYERS run (80 characters max):                TITLEP
'Nadir example calculation: AVHRR Ch.4'
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------
!..USER PROFILE (*USEPRO) [MANDATORY if *MODPRO is not supplied]
*USEPRO
!
!  1A. Filename of user's profile data set (80 characters max):     FNPROF
'ex1_layers_pro.dat'
!
!  2A. Filename of model profile data set to be used in conjunction
!      with user's profile for minor gas number densities etc
!      (80 characters max):                                         FNAFGL
'glatm.dat'
!
!  3A. Number of model profile to be used :                          MONO
!      1. Tropical            2. Midlatitude Summer
!      3. Midlatitude Winter  4. Subarctic Summer
!      5. Subarctic Winter    6. U.S. Standard
2
!
!  4A. Logical specifier for supplementing the user's gas
!      number density profiles from the model profile if
!      the former fall to zero at the user's profile levels :        WADD
!  4B. logical specifier for supplementing the user's profile
!      levels with model profile levels at higher altitude :        TOPADD
.FALSE., .FALSE.
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------
!..INTEGRATION PARAMETERS (*SUBLAY) [MANDATORY]
*SUBLAY
!
!  1A. Integration sub-layer accuracy :                               NP
!  1B. Refraction switch :                                          LREF
10,    .FALSE.
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------
!..FREQUENCY PARAMETERS (*FREQCY) [MANDATORY]
*FREQCY
!
!  1.A Lower wavenumber bound of proposed GENLN2 calculation :        V1
!  1.B Upper wavenumber bound of proposed GENLN2 calculation :        V2
850.0, 1000.0
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------
!..AUTOMATIC LAYERING (*DEFLAY)
!  [MANDATORY if and only if *USEPTH, *USELAY, and *GASLAY are not supplied]
*DEFLAY
!
!  Default layering controls:
!  1.A Max variation factor for average Voigt half width across a layer.
!      This value should lie between 1.0 and 2.0:                    WDIF
!  1.B Max temperature difference (K) across a layer at
!      the bottom of the atmosphere :                               TDIFB
!  1.C Max temperature difference (K) across a layer at
!      the top of the atmosphere :                                  TDIFT
2.0, 5.0, 30.0
!
!  2.A Atmosphere boundaries at height ('H') or pressure ('P') levels:  COOR
!  2.B Number of different path gases in each layer :               NOGAS
'H', 4
!
!  For each different layer path gas (IG=1,NOGAS) 1 input record
!  3.A Line file no to be used in output file for paths of this gas :  IFILE(IG)
!  3.B Molecular ID of gas :                                         LISTG(IG)
!  3.C Isotope ID of gas :                                           LISTI(IG)
!  4.C Line shape character string (8 Char.) to be used in
!      output file for paths of this gas :                          SHAPE(IG)
!  5.D Continuum character string specifier 'CON     ' or 'NOCON'
!      to be used in output file for paths of this gas :             CNTM(IG)
1,  1, 0, 'VOIGT',    'CON'
1,  2, 0, 'VOIGTCO2', 'CON'
1,  3, 0, 'VOIGT',    'NOCON'
1, 52, 0, 'XSECTION', 'NOCON'
!
!  4.A Atmosphere lower boundary (km if COOR='H' or mb if COOR='P') :   ALL
!  4.B Atmosphere upper boundary (km if COOR='H' or mb if COOR='P') :   ALU
!  4.C Ray initial zenith angle (theta_0) at bottom of atmosphere :  THETAA
0.0, 80.0, 0.0
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------
!..END OF LAYERS INPUT (*ENDINP) [MANDATORY]
*ENDINP
!!!!!!!! End of section !!!!!!!
```

91/12/05
17:28:48

Ex.1. Nadir View: Program LAYERS

ex1_layers_op.dat

1

```
! ***********************************************
! ***********************************************
! **  LAYERS: GENLN2 PATH PRE-PROCESSING        **
! **  ATMOSPHERIC LAYERING AND PATH GAS CURTIS  **
! **  GODSON CALCULATION                        **
! **  VERSION 3.0   D.P. EDWARDS   27/02/91     **
! **  (C) COPYRIGHT 1991 UCAR/NCAR              **
! **  ALL RIGHTS RESERVED                       **
! **  GENLN2 SOFTWARE AND RELATED MATERIALS MAY **
! **  BE USED ONLY UNDER AN EXECUTED VALID      **
! **  LICENCE AGREEMENT                         **
! ***********************************************
! ***********************************************
!
!
! TITLE OF THIS LAYERS RUN:
! Nadir example calculation: AVHRR Ch.4
!
! USER'S ATMOSPHERIC PROFILE TAKEN FROM:
! ex1_layers_pro.dat
!
!
!*************************************************************
!  ATMOSPHERIC PROFILE FOR MIDLATITUDE SUMMER:
!  GASES IMPORTANT FOR AVHRR CHANNEL 4.
!*************************************************************
! Data arrangement:
! Altitude (km), Pressure (mb), Temperature (K), Total Density (molecu
! Gas mixing ratios for listed gases (ppmv)
!
! AFGL MODEL USED: 2. Midlatiude Summer
!
! DEFAULT AVERAGE LAYERING FOR USE WITH ALL GASES.
! RESTRICTION FACTOR ON VOIGT HALF-WIDTH ACROSS A LAYER          =    2.00
! MAX. TEMPERATURE CHANGE ACROSS LAYER AT BOTTOM OF ATMOSPHERE =    5.00 K
! MAX. TEMPERATURE CHANGE ACROSS LAYER AT TOP OF ATMOSPHERE     =   30.00 K
! WAVENUMBER FOR DOPPLER WIDTH CALCULATION                       =  925.00 cm-1.
!
! ATMOSPHERIC REFRACTION NOT INCLUDED.
!
! INTEGRATION ACCURACY CRITERION PARAMETER =  10
!
! TOTAL NO. OF PATHS CALCULATED:
  96
!
! PATH   1 ** H2O ** HEIGHTS:    .000 -   1.100 km, 1.013E+03 - 8.915E+02 mb.
! RAY LENGTH =   1.1000 km, THETA = 0.0000E+00.
  1,  1, 0,        6.9506E-05,  291.911,  9.4306E-01,  1.5615E-02,   0.0
'VOIGT   '  'CON     '
! PATH   2 ** H2O ** HEIGHTS:   1.100 -   2.200 km, 8.915E+02 - 7.827E+02 mb.
! RAY LENGTH =   1.1000 km, THETA = 0.0000E+00.
  1,  1, 0,        4.3125E-05,  286.966,  8.2984E-01,  9.6400E-03,   0.0
'VOIGT   '  'CON     '
etc.

! PATH  24 ** H2O ** HEIGHTS:  71.400 -  80.000 km, 5.168E-02 - 1.048E-02 mb.
! RAY LENGTH =   8.6000 km, THETA = 0.0000E+00.
  1,  1, 0,        3.9663E-12,  206.369,  3.1573E-05,  1.1224E-10,   0.0
'VOIGT   '  'CON     '
! PATH  25 ** CO2 ** HEIGHTS:    .000 -   1.100 km, 1.013E+03 - 8.915E+02 mb.
! RAY LENGTH =   1.1000 km, THETA = 0.0000E+00.
  1,  2, 0,        1.4242E-06,  291.771,  9.3967E-01,  3.1009E-04,   0.0
'VOIGTCO2'  'CON     '
! PATH  26 ** CO2 ** HEIGHTS:   1.100 -   2.200 km, 8.915E+02 - 7.827E+02 mb.
! RAY LENGTH =   1.1000 km, THETA = 0.0000E+00.
  1,  2, 0,        1.2739E-06,  286.795,  8.2626E-01,  2.7266E-04,   0.0
'VOIGTCO2'  'CON     '
etc.

! PATH  48 ** CO2 ** HEIGHTS:  71.400 -  80.000 km, 5.168E-02 - 1.048E-02 mb.
! RAY LENGTH =   8.6000 km, THETA = 0.0000E+00.
  1,  2, 0,        4.2540E-10,  205.722,  3.0380E-05,  9.9161E-09,   0.0
'VOIGTCO2'  'CON     '
! PATH  49 ** O3 *** HEIGHTS:    .000 -   1.100 km, 1.013E+03 - 8.915E+02 mb.
! RAY LENGTH =   1.1000 km, THETA = 0.0000E+00.
  1,  3, 0,        1.3780E-10,  291.725,  9.3857E-01,  3.0010E-08,   0.0
'VOIGT   '  'NOCON   '
! PATH  50 ** O3 *** HEIGHTS:   1.100 -   2.200 km, 8.915E+02 - 7.827E+02 mb.
! RAY LENGTH =   1.1000 km, THETA = 0.0000E+00.
  1,  3, 0,        1.3769E-10,  286.747,  8.2525E-01,  2.9485E-08,   0.0
'VOIGT   '  'NOCON   '
etc.

! PATH  96 * CFC12 * HEIGHTS:  71.400 -  80.000 km, 5.168E-02 - 1.048E-02 mb.
! RAY LENGTH =   8.6000 km, THETA = 0.0000E+00.
  1, 52, 0,        1.3076E-30,  205.677,  3.0296E-05,  3.0296E-29,   0.0
'XSECTION'  'NOCON   '
!
!
!  PATHS    1 --   24
!  GAS ID  1 ** H2O **
!  TOTAL GAS COLUMN AMOUNT  [kg.moles/cm2] = 1.6448E-04
!  TOTAL RAY PATH LENGTH                [km] =     80.000
!  TOTAL EARTH CENTRED BENDING ANGLE [deg] = 0.0000E+00
!  TOTAL RAY PATH BENDING ANGLE      [deg] = 0.0000E+00
!
!  PATHS   25 --   48
!  GAS ID  2 ** CO2 **
!  TOTAL GAS COLUMN AMOUNT  [kg.moles/cm2] = 1.1826E-05
!  TOTAL RAY PATH LENGTH                [km] =     80.000
!  TOTAL EARTH CENTRED BENDING ANGLE [deg] = 0.0000E+00
!  TOTAL RAY PATH BENDING ANGLE      [deg] = 0.0000E+00
!
!  PATHS   49 --   72
!  GAS ID  3 ** O3 ***
!  TOTAL GAS COLUMN AMOUNT  [kg.moles/cm2] = 1.4975E-08
!  TOTAL RAY PATH LENGTH                [km] =     80.000
!  TOTAL EARTH CENTRED BENDING ANGLE [deg] = 0.0000E+00
!  TOTAL RAY PATH BENDING ANGLE      [deg] = 0.0000E+00
!
!  PATHS   73 --   96
!  GAS ID 52 * CFC12 *
!  TOTAL GAS COLUMN AMOUNT  [kg.moles/cm2] = 1.9708E-11
!  TOTAL RAY PATH LENGTH                [km] =     80.000
!  TOTAL EARTH CENTRED BENDING ANGLE [deg] = 0.0000E+00
!  TOTAL RAY PATH BENDING ANGLE      [deg] = 0.0000E+00
```

Ex.1. Nadir View: Program GENLN2
ex1_genln2_ip.dat


```
!
!
!                 ******************************************
!                 *                                        *
!                 *         PROGRAM GENLN2: INPUT FILE     *
!                 *         --------------------------     *
!                 *  INPUT FILE FOR THE GENLN2 LINE-BY-LINE *
!                 *  COMPUTER MODEL. CALCULATES ATMOSPHERIC *
!                 *  TRANSMITTANCE AND RADIANCE.            *
!                 *  VERSION 3.0: D.P. EDWARDS 21/08/90     *
!                 *                                        *
!                 ******************************************
!                                                   INPUT PARAMETER NAME
!-----------------------------------------------------------------------------
!..TITLE INFORMATION AND SUMMARY OUTPUT SPECIFICATION FOR THIS GENLN2 RUN
!..(*TITLES) [MANDATORY]
*TITLES
!
!      1A. Title of this GENLN2 run (40 characters MAX) :                TITLE
'Nadir example calculation: AVHRR Ch.4'
!
!      2A. Passband average spectral values only are printed in
!          formatted summary output file if logical is set true:         AVER
!      2B. Mixing table not printed if logical is set true:              MXER
.FALSE., .TRUE.
!
!      Data to be printed in the formatted summary output file is
!      specified by the IDAT parameter for the following categories:-
!      IDAT = 1  Path integrated transmittance spectrum.
!           = 2  Mixed path integrated transmittance spectrum.
!           = 3  Radiating atmosphere layer integrated
!                transmittance and radiance spectra.
!      The following section is repeated for each required IDAT.
!----------
!      3A. Index (1,2 or 3 above):                                       IDAT
2
!
!      If  IDAT = 1 or IDAT = 2:
!      4A. No. of paths or mixed paths to be printed: NP;
!          if all paths are to be print set NP<0.
!      Else if IDAT=3:
!      4A. Atmosphere no. for printing:                                  IATM
!          if all atmospheres are to be printed set IATM<0.
!      4B. no. of layers to be printed:                                   NP
!          if all layers are to be printed set NP<0.
4
!
!      For all IDAT:
!      5A. List of path, mixed path or layer nos. for printing;
!          only required if NP>0:                   (IOPDT(IDAT,IATM,I),I=1,NP)
25 26 27 28
!----------
3
1, 1
24
!----------
3
2, 1
19
!----------
3
3, 1
13
!----------
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..THE GAS LINE DATA FILE(S) TO BE USED (*GASFIL) [MANDATORY]
*GASFIL
!
!      1A. No. of line data files to be read:                            NFILE
!      1B. Machine specifier, determines record length:                   MACH
!          MACH=1: 4 byte/word, OPEN RECL in words (eg. VAX, ANSII stand)
!          MACH=2: 4 byte/word, OPEN RECL in bytes (eg. IBM RISC)
!          MACH=3: 8 byte/word, OPEN RECL in bytes (eg. CRAY)
!          This should be the same as was used in HITLIN
1, 2
!
!      For each file (IFILE=1,NFILE) 4 input records
!----------
!      2A. Filename of line data file:                              FNAM(IFILE)
'ex1_hitlin_op.dat'
!
!      3A. No. of gases to be read from this file:                  NGAS(IFILE)
3
!
!      4A. Molecular ID's of the gas(es) to be read:
!                                   (LGASES(IFILE,IGAS),IGAS=1,NGAS(IFILE))
1,  2,  3
!
!      5A. Line data version(s) to be chosen:
!                                   (LCHOSE(IFILE,IGAS),IGAS=1,NGAS(IFILE))
10, 10, 10
!----------
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..THE GAS CROSS-SECTION DATA FILE(S) TO BE USED (*XSCFIL) [NOT MANDATORY]
*XSCFIL
!
!      1A. No. of xsec data files to be read:                           NXSFIL
1
!
!      For each file (IFILE=1,NXSFIL) 3 input records
!----------
!      2A. Filename of xsec data file:                            FXSNAM(IFILE)
'xsec.dat'
!
!      3A. No. of gas xsecs to be read from this file:            NXSEC(IFILE)
1
!
!      4A. Molecular ID's of the xsec gas(es) to be read:
!                                   (LXSEC(IFILE,IGAS),IGAS=1,NXSEC(IFILE))
52
!----------
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..DEFAULT CALCULATION OF WIDE MESH BOUNDARY WAVENUMBER GRID (*DEFGRD)
!..[MANDATORY if one of *USEGRD, *GRDFIL or *RADIOM is not supplied]
*DEFGRD
!
!      1A. The minimum wavenumber to be considered (cm-1):                FMIN
!      1B. the lower integration (passband) wavenumber (cm-1):            FPSL
!      1C. the upper integration (passband) wavenumber (cm-1):            FPSU
!      1D. the maximum wavenumber to be considered (cm-1):                FMAX
!      1E. the wide mesh constant wavenumber interval spacing (cm-1):    DELTA
825.0, 850.0, 1000.0, 1025.0,    1.0
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..PARAMETERS DEFINING THE SPECTRAL CALCULATION REGIONS (*SPECTM)
```

Ex.1. Nadir View: Program GENLN2
ex1_genln2_ip.dat


```
!..(MANDATORY with *USEGRD, *GRDFIL or *DEFGRD.
!..Must not appear if *RADIOM is supplied)
*SPECTM
!       1A. The wavenumber range either side of a wide mesh interval for
!           which a fine grid line-by-line calculation is performed (cm-1):  FEXC
!       1B. the wavenumber range either side of the current interval
!           outside of which lines are not considered (cm-1):                FWIND
!       1C. the parameter specifying the division of the wide mesh
!           wavenumber interval to produce the fine mesh wavenumber grid:    NDIV
1.0, 25.0, 500
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..PATH PARAMETERS READ FROM EXTERNAL FILE, EG. LAYERS OUTPUT FILE (*PTHFIL)
*PTHFIL
!
!       1A. File name of external path parameter file:                    PFNAM
'ex1_layers_op.dat'
!
!       File PFNAM then contains the same information as the
!       *PTHPAR section beginning with input record 2
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..MIXING PATHS TO FORM ATMOSPHERIC MIXED PATHS (*MIXING) [NOT MANDATORY]
*MIXING
!
!       1A. No. of mixed paths to be calculated:                          NPMIX
28
!
!       Mixing table is of length NPATH and depth NPMIX:
!       (remember NPATH is the sum of the number of paths read
!       in the *PTHPAR and the *PTHFIL sections)
!       The required mixing table parameters are:-
!                                                                         IPMIX
!       2A. The mixed path index:
!       2B. the mixing table:                 (TABMIX(IPATH,IPMIX),IPATH=1,NPATH))
!       Each new mixed path must begin a new line, and the
!       input field must not exceed 130 characters.
!
  1  ROT0   1 ROT23  ROT0   1 ROT23  ROT0   1 ROT23  ROT0   1 ROT23
  2  ROT1   1 ROT22  ROT1   1 ROT22  ROT1   1 ROT22  ROT1   1 ROT22
  3  ROT2   1 ROT21  ROT2   1 ROT21  ROT2   1 ROT21  ROT2   1 ROT21
  4  ROT3   1 ROT20  ROT3   1 ROT20  ROT3   1 ROT20  ROT3   1 ROT20
  5  ROT4   1 ROT19  ROT4   1 ROT19  ROT4   1 ROT19  ROT4   1 ROT19
  6  ROT5   1 ROT18  ROT5   1 ROT18  ROT5   1 ROT18  ROT5   1 ROT18
  7  ROT6   1 ROT17  ROT6   1 ROT17  ROT6   1 ROT17  ROT6   1 ROT17
  8  ROT7   1 ROT16  ROT7   1 ROT16  ROT7   1 ROT16  ROT7   1 ROT16
  9  ROT8   1 ROT15  ROT8   1 ROT15  ROT8   1 ROT15  ROT8   1 ROT15
 10  ROT9   1 ROT14  ROT9   1 ROT14  ROT9   1 ROT14  ROT9   1 ROT14
 11  ROT10  1 ROT13  ROT10  1 ROT13  ROT10  1 ROT13  ROT10  1 ROT13
 12  ROT11  1 ROT12  ROT11  1 ROT12  ROT11  1 ROT12  ROT11  1 ROT12
 13  ROT12  1 ROT11  ROT12  1 ROT11  ROT12  1 ROT11  ROT12  1 ROT11
 14  ROT13  1 ROT10  ROT13  1 ROT10  ROT13  1 ROT10  ROT13  1 ROT10
 15  ROT14  1 ROT9   ROT14  1 ROT9   ROT14  1 ROT9   ROT14  1 ROT9
 16  ROT15  1 ROT8   ROT15  1 ROT8   ROT15  1 ROT8   ROT15  1 ROT8
 17  ROT16  1 ROT7   ROT16  1 ROT7   ROT16  1 ROT7   ROT16  1 ROT7
 18  ROT17  1 ROT6   ROT17  1 ROT6   ROT17  1 ROT6   ROT17  1 ROT6
 19  ROT18  1 ROT5   ROT18  1 ROT5   ROT18  1 ROT5   ROT18  1 ROT5
 20  ROT19  1 ROT4   ROT19  1 ROT4   ROT19  1 ROT4   ROT19  1 ROT4
 21  ROT20  1 ROT3   ROT20  1 ROT3   ROT20  1 ROT3   ROT20  1 ROT3
 22  ROT21  1 ROT2   ROT21  1 ROT2   ROT21  1 ROT2   ROT21  1 ROT2
 23  ROT22  1 ROT1   ROT22  1 ROT1   ROT22  1 ROT1   ROT22  1 ROT1
 24  ROT23  1 ROT0   ROT23  1 ROT0   ROT23  1 ROT0   ROT23  1 ROT0
!
 25  R1T24          ROT24          ROT24          ROT24
 26  ROT24          R1T24          ROT24          ROT24
 27  ROT24          ROT24          R1T24          ROT24
 28  ROT24          ROT24          ROT24          R1T24
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..RADIANCE CALCULATION (*RADNCE) [NOT MANDATORY]
*RADNCE
!
!       1A. No. of radiating atmospheres to be calculated:                NATM
3
!       For each atmosphere (IATM=1,NATM) 3 input records
!----------
!       Layer table data consists of the following:-
!       2A. The radiating atmosphere index:                               IATM
!       2B. the viewing parameter:                                   IVIEW(IATM)
!       2C. the layer emission parameter:                             IEMS(IATM)
!       2D. the no. of layers in the atmosphere:                      NLAY(IATM)
!       2E. path or mixed path specifier for total layer absorption:  LAYSP(IATM)
!       2F. the path (LAYSP(IATM)=1) or mixed path nos.(LAYSP(IATM)=2)
!           to be used to specify the layer total absorption in order
!           of radiation travel:            (LAYER(ILAY,IATM),ILAY=1,NLAY(IATM))
1, 2, 1, 24, 2,
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
!
!       If IVIEW(IATM)=2 then the initiating surface parameters are supplied:
!       3A. Atmospheric boundary temperature (K):                     TBDY(IATM)
!       3B. temperature of the initiating surface:                   TINIT(IATM)
!       3C. emissivity of initiating surface:                        EMSTY(IATM)
2.96, 293.2, 0.9889
!
!       If IEMS(IATM)=2 different paths/mixed paths can to be used for
!       layer emission to those used for layer transmittance:
!       4A. path or mixed path specifer for emission layer absorption:LEMSP(IATM)
!       4B. the path (LEMSP(IATM)=1) or mixed-path nos.(LEMSP(IATM)=2)
!           to be used to specify the layer emission in order
!           in order of radiation travel:   (LAYEMS(ILAY,IATM),ILAY=1,NLAY(IATM))
!LEMSP(1), LAYEMS(1,1) LAYEMS(2,1) LAYEMS(3,1) .... LAYEMS(NLAY(1),1)
!----------
2, 2, 1, 19, 2,
6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24
2.96, 265.0  1.0
!----------
3, 2, 1, 13, 2,
12 13 14 15 16 17 18 19 20 21 22 23 24
2.96, 230.0  1.0
!----------
!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..INTEGRATION SWITCH (*INTEGN) [NOT MANDATORY]
*INTEGN
!       Logical switch. When present the transmittance and radiance
!       spectra are integrated over each wide mesh interval.
!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..UNFORMATTED OUTPUT FILE SPECIFICATION (*OUTPUT) [NOT MANDATORY]
*OUTPUT
!
!       1A. File name of output file:                                     OPFNAM
'ex1_genln2_ops.dat'
!
!       Data to be output is specified by IDAT parameter
!       for the following categories:-
!       IDAT= 1  Path point transmission spectrum;
!           = 2  Path integrated transmission spectrum;
!           = 3  Mixed path point transmission spectrum;
```

Ex.1. Nadir View: Program GENLN2
ex1_genln2_ip.dat


```
!          = 4  Mixed path integrated transmission spectrum;
!          = 5  Layer point transmission spectrum;
!          = 6  Layer integrated transmission spectrum;
!          = 7  Layer point radiance spectrum;
!          = 8  Layer integrated radiance spectrum.
!      The following section is repeated for each required IDAT.
!----------
!      2A. Index (1 thro' 8 above):                                    IDAT
3
!
!      For IDAT = 1, 2, 3 or 4:
!      3A. no. of paths or mixed paths to be output:                     NP
!          if all paths are to be printed set NP<0.
!      For IDAT = 5, 6, 7 or 8:
!      3A. atmosphere no. for output:                                  IATM
!          if all atmospheres are to be output set IATM<0.
!      3B. no. of layers to be output:                                   NP
!          if all layers are to be output set NP<0.
4
!
!      For all IDAT:
!      4A. List of path, mixed path or layer nos. for output;
!          only required if NP>0:                    (IOPGR(IDAT,IATM,I),I=1,NP)
25 26 27 28
!----------
7
1, 1
24
!----------
7
2, 1
19
!----------
7
3, 1
13
!----------
8
1, 1
24
!----------
8
2, 1
19
!----------
8
3, 1
13
!----------
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..END OF GENLN2 INPUT (*ENDINP) [MANDATORY]
*ENDINP
!!!!!!! End of input data to GENLN2 !!!!!!!
```

```
************************************************
************************************************
**  GENLN2: GENERAL LINE-BY-LINE ATMOSPHERIC  **
**  TRANSMITTANCE AND RADIANCE MODEL          **
**  VERSION 3.0   D.P. EDWARDS   27/02/91     **
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**  GENLN2 SOFTWARE AND RELATED MATERIALS     **
**  MAY BE USED ONLY UNDER AN EXECUTED VALID  **
**  LICENCE AGREEMENT                         **
************************************************
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DATE (DAY.MON.YR):  20.12.91


*************** CHECK INPUT DATA FOR ERRORS ***************

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*************** INPUT DATA SUCCESSFULLY READ ***************

*************** SUMMARY OF INPUT DATA ***************

TITLE OF THIS RUN :- Nadir example calculation: AVHRR Ch.4

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LINE AND CROSS-SECTION DATA
***************************
 1 LINE DATA FILE(S) WILL BE USED
FILE NO.  1 FILENAME ex1_hitlin_op.dat
 3 GAS(ES) TO BE READ, MOLEC ID NO(S):-      1    2    3
GAS LINE VERSION(S) TO BE CHOSEN:-         10   10   10

 1 XSEC DATA FILE(S) WILL BE USED
FILE NO.  1 FILENAME xsec.dat
 1 XSEC(S) TO BE READ, MOLEC ID NO(S):-    52
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

WAVENUMBER GRID
***************
TOTAL WAVENUMBER RANGE CONSIDERED         825.000 -    1025.000 cm-1
PASSBAND (INTEGRATION) WAVENUMBER RANGE   850.000 -    1000.000 cm-1
THIS CONSISTS OF   150 INTERVALS OF AVERAGE WAVENUMBER WIDTH     1.000 cm-1
EACH INTERVAL WILL BE DIVIDED INTO    500 FINE MESHES FOR THE TRANSMITTANCE CALCULATION.
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

TRANSMITTANCE CALCULATION
*************************
THE LINE ABSORPTION IN A RANGE OF   1.000 cm-1 EITHER SIDE OF THE WIDEMESH INTERVAL WILL BE TREATED EXPLICITLY.
THE WING ABSORPTION DUE TO LINES LYING IN THE RANGE   1.000 -   25.000 cm-1
EITHER SIDE OF THE WIDEMESH INTERVAL WILL BE INCLUDED.
THE CONTINUUM ABSORPTION WILL BE INCLUDED FOR APPROPRIATE PATHS.
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

```
 PATH DATA
 *********
 PATH  FILE  GAS ID  ISO ID  AMT kg.moles/cm2      T K      P atm  PARTP atm   VEL m/s  LINESHAPE  CONTINUUM
 --------------------------------------------------------------------------------------------------------------
    1    1       1       0          6.951E-05  291.911  9.431E-01  1.562E-02  0.000E+00   VOIGT      CON
    2    1       1       0          4.313E-05  286.966  8.298E-01  9.640E-03  0.000E+00   VOIGT      CON
    3    1       1       0          2.086E-05  281.543  7.352E-01  5.721E-03  0.000E+00   VOIGT      CON
    4    1       1       0          1.251E-05  276.124  6.583E-01  3.333E-03  0.000E+00   VOIGT      CON
etc.

   93    1      52       0          6.652E-18  272.120  1.343E-03  3.115E-16  0.000E+00   XSECTION   NOCON
   94    1      52       0          3.324E-26  247.872  1.962E-04  1.962E-24  0.000E+00   XSECTION   NOCON
   95    1      52       0          5.769E-27  230.602  1.047E-04  1.047E-24  0.000E+00   XSECTION   NOCON
   96    1      52       0          1.308E-30  205.677  3.030E-05  3.030E-29  0.000E+00   XSECTION   NOCON
 !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

 MIXING TABLE DATA
 *****************
 MIXING TABLE IS OF LENGTH  96 PATH(S) AND DEPTH  28 MIXED PATH(S)

 !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

 RADIANCE DATA
 *************
 CALCULATIONS WILL BE PERFORMED FOR   3 RADIATING ATMOSPHERE(S)

 ATMOSPHERE  NO LAY PTH/MIX   PATH/MIXED PATH NOS TO BE USED FOR LAYER TRANSMITTANCE IN ORDER OF THE DIRECTION OF RADIATION TRAVEL
 --------------------------------------------------------------------------------------------------------------------------------------

          1      24        2      1   2   3   4   5   6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24
 VIEWING  PARAMETER =  2   ATMOSPHERIC BOUNDARY TEMP. (K) =    2.960   SURFACE EMITTANCE =   .98890   SURFACE TEMP. (K) =  293.200

          2      19        2      6   7   8   9  10  11  12  13  14  15  16  17  18  19  20  21  22  23  24
 VIEWING  PARAMETER =  2   ATMOSPHERIC BOUNDARY TEMP. (K) =    2.960   SURFACE EMITTANCE =  1.00000   SURFACE TEMP. (K) =  265.000

          3      13        2     12  13  14  15  16  17  18  19  20  21  22  23  24
 VIEWING  PARAMETER =  2   ATMOSPHERIC BOUNDARY TEMP. (K) =    2.960   SURFACE EMITTANCE =  1.00000   SURFACE TEMP. (K) =  230.000
 !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

 SPECTRA WILL BE INTEGRATED OVER THE WIDEMESH INTERVALS.
 !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

 *************** CALCULATION BEGINS ***************

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 *************** ELAPSED CPU TIME:    2:17:38.13 ***************


 *************** CALCULATION COMPLETE. ***************
 !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

 INTEGRATED MIXED PATH TRANSMITTANCES
 ************************************

 *** MIXED PATH NO.   25 ***
```

```
 INTERVAL  LOW BDY cm-1  UPP BDY cm-1  FINE MESHES    TRANSMITTANCE
 -------------------------------------------------------------------
        1       850.000       851.000          500      .359862E+00
        2       851.000       852.000          500      .660303E+00
        3       852.000       853.000          500      .603862E+00
etc.

      148       997.000       998.000          500      .818423E+00
      149       998.000       999.000          500      .810427E+00
      150       999.000      1000.000          500      .719268E+00
 AVERAGE VALUE OVER PASSBAND                            .714597E+00

 *** MIXED PATH NO.   26 ***
 INTERVAL  LOW BDY cm-1  UPP BDY cm-1  FINE MESHES    TRANSMITTANCE
 -------------------------------------------------------------------
        1       850.000       851.000          500      .999121E+00
        2       851.000       852.000          500      .999402E+00
        3       852.000       853.000          500      .999660E+00
etc.

      148       997.000       998.000          500      .999132E+00
      149       998.000       999.000          500      .999743E+00
      150       999.000      1000.000          500      .999131E+00
 AVERAGE VALUE OVER PASSBAND                            .986363E+00

 *** MIXED PATH NO.   27 ***
 INTERVAL  LOW BDY cm-1  UPP BDY cm-1  FINE MESHES    TRANSMITTANCE
 -------------------------------------------------------------------
        1       850.000       851.000          500      .999963E+00
        2       851.000       852.000          500      .999950E+00
        3       852.000       853.000          500      .999977E+00
etc.

      148       997.000       998.000          500      .914000E+00
      149       998.000       999.000          500      .871733E+00
      150       999.000      1000.000          500      .870319E+00
 AVERAGE VALUE OVER PASSBAND                            .991805E+00

 *** MIXED PATH NO.   28 ***
 INTERVAL  LOW BDY cm-1  UPP BDY cm-1  FINE MESHES    TRANSMITTANCE
 -------------------------------------------------------------------
        1       850.000       851.000          500      .100000E+01
        2       851.000       852.000          500      .100000E+01
        3       852.000       853.000          500      .100000E+01
etc.

      148       997.000       998.000          500      .100000E+01
      149       998.000       999.000          500      .100000E+01
      150       999.000      1000.000          500      .100000E+01
 AVERAGE VALUE OVER PASSBAND                            .995772E+00

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 INTEGRATED ATMOSPHERIC LAYER TRANSMITTANCES AND BOUNDARY RADIANCES
 *******************************************************************

 *** ATMOSPHERE   1 ***
```
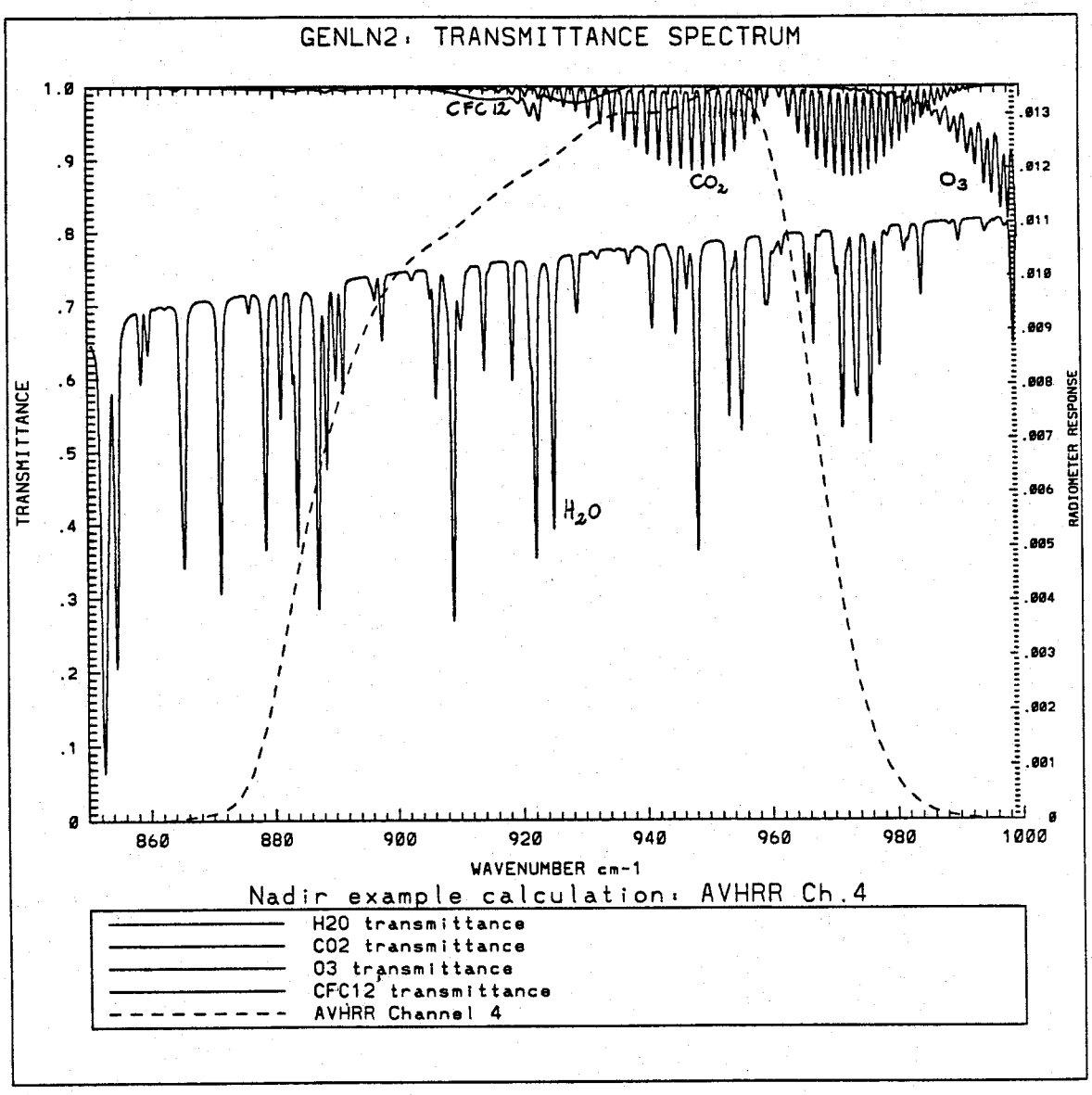

```
*** LAYER NO.   24 ***
INTERVAL  LOW BDY cm-1  UPP BDY cm-1  FINE MESHES    TRANSMITTANCE     BDY RADIANCE
                                                                      W/(m2.sr.cm-1)
-------------------------------------------------------------------------------------
       1       850.000       851.000          500      .359468E+00      .103922E+00
       2       851.000       852.000          500      .659876E+00      .110991E+00
       3       852.000       853.000          500      .603635E+00      .110248E+00
etc.

     147       996.000       997.000          500      .721097E+00      .809996E-01
     148       997.000       998.000          500      .747411E+00      .823899E-01
     149       998.000       999.000          500      .705887E+00      .797261E-01
     150       999.000      1000.000          500      .623999E+00      .786304E-01
AVERAGE VALUES OVER PASSBAND                          .694896E+00      .975753E-01

*** ATMOSPHERE   2 ***

*** LAYER NO.   19 ***
INTERVAL  LOW BDY cm-1  UPP BDY cm-1  FINE MESHES    TRANSMITTANCE     BDY RADIANCE
                                                                      W/(m2.sr.cm-1)
-------------------------------------------------------------------------------------
       1       850.000       851.000          500      .931149E+00      .725256E-01
       2       851.000       852.000          500      .994890E+00      .729145E-01
       3       852.000       853.000          500      .992876E+00      .727609E-01
etc.

     148       997.000       998.000          500      .919950E+00      .507644E-01
     149       998.000       999.000          500      .879940E+00      .495883E-01
     150       999.000      1000.000          500      .874501E+00      .494062E-01
AVERAGE VALUES OVER PASSBAND                          .977949E+00      .622611E-01

*** ATMOSPHERE   3 ***

*** LAYER NO.   13 ***
INTERVAL  LOW BDY cm-1  UPP BDY cm-1  FINE MESHES    TRANSMITTANCE     BDY RADIANCE
                                                                      W/(m2.sr.cm-1)
-------------------------------------------------------------------------------------
       1       850.000       851.000          500      .999057E+00      .360143E-01
       2       851.000       852.000          500      .999915E+00      .359162E-01
       3       852.000       853.000          500      .999934E+00      .358169E-01
etc.

     148       997.000       998.000          500      .930116E+00      .232589E-01
     149       998.000       999.000          500      .892822E+00      .232763E-01
     150       999.000      1000.000          500      .892637E+00      .231814E-01
AVERAGE VALUES OVER PASSBAND                          .991183E+00      .291857E-01


*************** END OF DATA OUTPUT ***************


*************** GRAPHICS FILE WRITTEN TO: ex1_genln2_ops.dat                    ***************
```

Ex.1. Nadir View: Program GENGRP

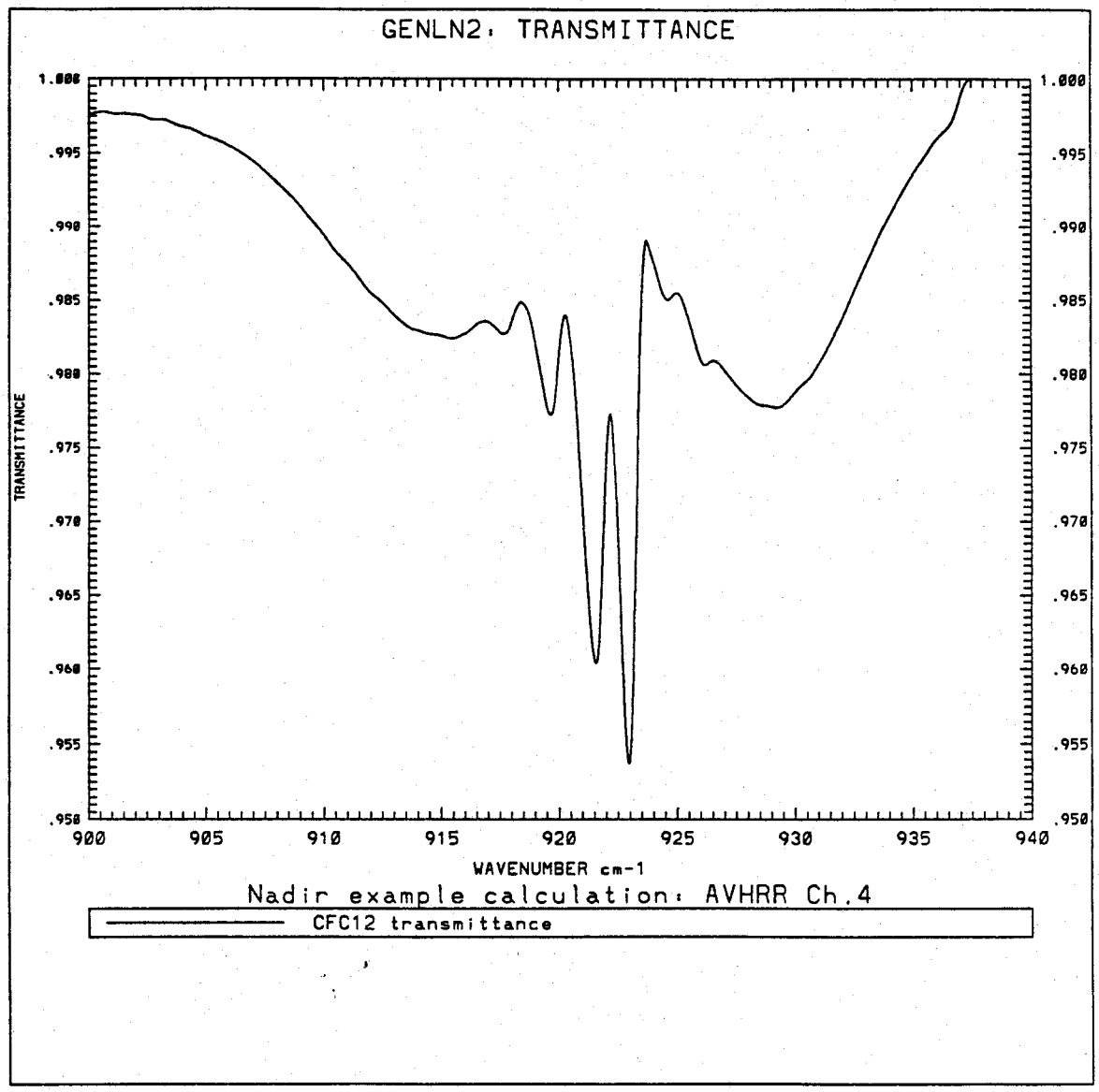
ex1_gengrp_trans.dat


```
##################################################
##################################################
##                PROGRAM GENGRP                 ##
##                --------------                 ##
##  GENERAL PURPOSE GRAPHICS FOR PLOTTING        ##
##  GENLN2 TRANSMITTANCE AND RADIANCE SPECTRA    ##
##  VERSION 3.0    D.P. EDWARDS    27/02/91      ##
##  (C) COPYRIGHT 1991 UCAR/NCAR                 ##
##  ALL RIGHTS RESERVED                          ##
##  GENLN2 SOFTWARE AND RELATED MATERIALS MAY    ##
##  BE USED ONLY UNDER AN EXECUTED VALID         ##
##  LICENCE AGREEMENT                            ##
##################################################
##################################################
**Q** Name of GENLN2 unformatted output file to plot? :
ex1_genln2_ops.dat
**Q** Enter filename of output graphics metacode file :
ex1_gengrp_trans.meta
**Q** Do you want the default picture size [Y/N] :
Y
**Q** For a default axis, the axis drawn will be
      that appropriate for the first curve entered.
      Is a default X-axis to be drawn? [Y/N] :
Y
**Q** Is a default Y-axis to be drawn? [Y/N] :
Y
**Q** Enter the no. of curves to be plotted on this graph? :
4
**Q** Do you want to supply your own curve captions? [Y/N] :
Y
##### CURVE NO.  1 #####
**Q** Is a path transmittance spectrum                    (PT),
      a mixed path transmittance spectrum                 (XT),
      a radiating atmosphere layer transmittance spectrum (AT),
      or a radiating atmosphere layer radiance spectrum   (AR)
      to be plotted?
      Enter one of PT, XT, AT or AR :
XT
**Q** Curve   1. IPMIX no. of mixed path to be plotted? :
25
**Q** Are wide mesh binned spectral values to be plotted? [Y/N] :
N
**Q** Enter line type and pen type for drawing curve LTYPE,IPEN :
1,2
**Q** Enter curve caption, 50 chars. max. :
H2O transmittance
##### CURVE NO.  2 #####
**Q** Is a path transmittance spectrum                    (PT),
      a mixed path transmittance spectrum                 (XT),
      a radiating atmosphere layer transmittance spectrum (AT),
      or a radiating atmosphere layer radiance spectrum   (AR)
      to be plotted?
      Enter one of PT, XT, AT or AR :
XT
**Q** Curve   2. IPMIX no. of mixed path to be plotted? :
26
**Q** Are wide mesh binned spectral values to be plotted? [Y/N] :
N
**Q** Enter line type and pen type for drawing curve LTYPE,IPEN :
1,3
**Q** Enter curve caption, 50 chars. max. :
CO2 transmittance
##### CURVE NO.  3 #####
**Q** Is a path transmittance spectrum                    (PT),
      a mixed path transmittance spectrum                 (XT),
      a radiating atmosphere layer transmittance spectrum (AT),
      or a radiating atmosphere layer radiance spectrum   (AR)
      to be plotted?
      Enter one of PT, XT, AT or AR :
XT
**Q** Curve   3. IPMIX no. of mixed path to be plotted? :
27
**Q** Are wide mesh binned spectral values to be plotted? [Y/N] :
N
**Q** Enter line type and pen type for drawing curve LTYPE,IPEN :
1,4
**Q** Enter curve caption, 50 chars. max. :
O3 transmittance
##### CURVE NO.  4 #####
**Q** Is a path transmittance spectrum                    (PT),
      a mixed path transmittance spectrum                 (XT),
      a radiating atmosphere layer transmittance spectrum (AT),
      or a radiating atmosphere layer radiance spectrum   (AR)
      to be plotted?
      Enter one of PT, XT, AT or AR :
XT
**Q** Curve   4. IPMIX no. of mixed path to be plotted? :
28
**Q** Are wide mesh binned spectral values to be plotted? [Y/N] :
N
**Q** Enter line type and pen type for drawing curve LTYPE,IPEN :
1,5
**Q** Enter curve caption, 50 chars. max. :
CFC12 transmittance
**Q** Do you want to degrade the spectra with an
      instrument line shape (ILS) function? [Y/N] :
Y
**Q** ILS function type specifier;
      1 = square boxcar
      2 = triangle
      3 = Fourier spec. (only with evenly spaced points)
      4 = user supplied (only with evenly spaced points)
      Enter 1,2,3 or 4 :
2
**Q** Enter triangle half power band width in cm-1 :
0.5
**Q** Are all points to be plotted? [Y/N] :
N
**Q** Enter no of plot points/cm-1 :
50
**Q** Is an external spectra to be plotted? [Y/N] :
Y
**Q** Enter number of external spectra for plotting :
1
##### EXTERNAL SPECTRUM NO.  1 #####
**Q** Enter name of file containing spectrum data :
ex1_gengrp_res.dat
**Q** Enter line type and pen type for drawing curve LTYPE,IPEN :
2,1
**Q** Enter spectrum caption, 50 chars. max. :
AVHRR Channel 4
**Q** Enter spectrum plot Y-axis title :
RADIOMETER RESPONSE
```


GENLN2: TRANSMITTANCE SPECTRUM
TRANSMITTANCE
RADIOMETER RESPONSE
WAVENUMBER cm-1
CFC12
CO2
O3
H2O
Nadir example calculation: AVHRR Ch.4
H2O transmittance
CO2 transmittance
O3 transmittance
CFC12 transmittance
AVHRR Channel 4

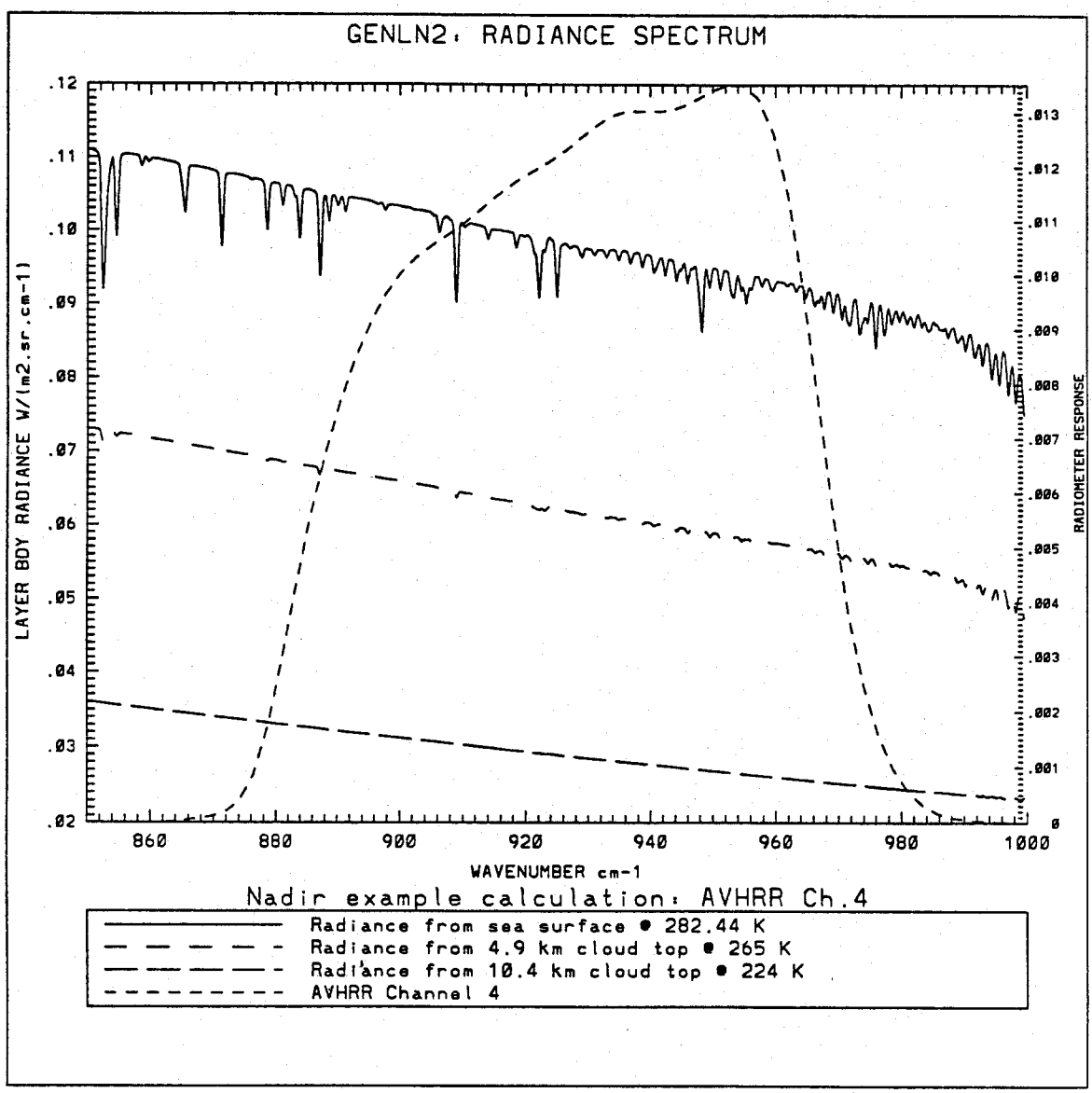
Ex.1. Nadir View: Program GENGRP
ex1_gengrp_cfc12.dat


```
##############################################
##############################################
##                PROGRAM GENGRP            ##
##                --------------            ##
##  GENERAL PURPOSE GRAPHICS FOR PLOTTING   ##
##  GENLN2 TRANSMITTANCE AND RADIANCE SPECTRA ##
##  VERSION 3.0   D.P. EDWARDS   27/02/91   ##
##  (C) COPYRIGHT 1991 UCAR/NCAR            ##
##  ALL RIGHTS RESERVED                     ##
##  GENLN2 SOFTWARE AND RELATED MATERIALS MAY ##
##  BE USED ONLY UNDER AN EXECUTED VALID    ##
##  LICENCE AGREEMENT                       ##
##############################################
##############################################


**Q** Name of GENLN2 unformatted output file to plot? :
ex1_genln2_ops.dat
**Q** Enter filename of output graphics metacode file :
ex1_gengrp_cfc12.meta
**Q** Do you want the default picture size [Y/N] :
Y
**Q** For a default axis, the axis drawn will be
      that appropriate for the first curve entered.
      Is a default X-axis to be drawn? [Y/N] :
N
**Q** Is a default Y-axis to be drawn? [Y/N] :
N
**Q** Enter XMIN and XMAX values for user's X axis :
900.0, 940.0
**Q** Enter X axis title :
WAVENUMBER cm-1
**Q** Are normalized spectra to be plotted? [Y/N] :
N
**Q** Enter YMIN and YMAX values for user's Y axis :
0.95, 1.0
**Q** Enter 1 for linear scale, 2 for log scale :
1
**Q** Enter Y axis title :
TRANSMITTANCE
**Q** Enter graph title :
GENLN2: TRANSMITTANCE
**Q** Enter the no. of curves to be plotted on this graph? :
1
**Q** Do you want to supply your own curve captions? [Y/N] :
Y
##### CURVE NO.  1 #####
**Q** Is a path transmittance spectrum                    (PT),
      a mixed path transmittance spectrum                 (XT),
      a radiating atmosphere layer transmittance spectrum (AT),
      or a radiating atmosphere layer radiance spectrum   (AR)
      to be plotted?
      Enter one of PT, XT, AT or AR :
XT
**Q** Curve   1. IPMIX no. of mixed path to be plotted? :
28
**Q** Are wide mesh binned spectral values to be plotted? [Y/N] :
N
**Q** Enter line type and pen type for drawing curve LTYPE,IPEN :
1,5
**Q** Enter curve caption, 50 chars. max. :
CFC12 transmittance
**Q** Do you want to degrade the spectra with an
      instrument line shape (ILS) function? [Y/N] :
Y
**Q** ILS function type specifier;
      1 = square boxcar
      2 = triangle
      3 = Fourier spec. (only with evenly spaced points)
      4 = user supplied (only with evenly spaced points)
      Enter 1,2,3 or 4 :
2
**Q** Enter triangle half power band width in cm-1 :
0.5
**Q** Are all points to be plotted? [Y/N] :
N
**Q** Enter no of plot points/cm-1 :
50
**Q** Is an external spectra to be plotted? [Y/N] :
N
```


GENLN2: TRANSMITTANCE
TRANSMITTANCE
1.000
.995
.990
.985
.980
.975
.970
.965
.960
.955
.950
900
905
910
915
920
925
930
935
940
WAVENUMBER cm-1
Nadir example calculation: AVHRR Ch.4
CFC12 transmittance

Ex.1. Nadir View: Program GENGRP
ex1_gengrp_rad.dat


```
##############################################
##############################################
##                PROGRAM GENGRP            ##
##                --------------            ##
##  GENERAL PURPOSE GRAPHICS FOR PLOTTING   ##
##  GENLN2 TRANSMITTANCE AND RADIANCE SPECTRA ##
##  VERSION 3.0   D.P. EDWARDS   27/02/91   ##
##  (C) COPYRIGHT 1991 UCAR/NCAR            ##
##  ALL RIGHTS RESERVED                     ##
##  GENLN2 SOFTWARE AND RELATED MATERIALS MAY ##
##  BE USED ONLY UNDER AN EXECUTED VALID    ##
##  LICENCE AGREEMENT                       ##
##############################################
##############################################


**Q** Name of GENLN2 unformatted output file to plot? :
ex1_genln2_ops.dat
**Q** Enter filename of output graphics metacode file :
ex1_gengrp_rad.meta
**Q** Do you want the default picture size [Y/N] :
Y
**Q** For a default axis, the axis drawn will be
      that appropriate for the first curve entered.
      Is a default X-axis to be drawn? [Y/N] :
Y
**Q** Is a default Y-axis to be drawn? [Y/N] :
Y
**Q** Enter the no. of curves to be plotted on this graph? :
3
**Q** Do you want to supply your own curve captions? [Y/N] :
Y
##### CURVE NO.  1 #####
**Q** Is a path transmittance spectrum                    (PT),
      a mixed path transmittance spectrum                 (XT),
      a radiating atmosphere layer transmittance spectrum (AT),
      or a radiating atmosphere layer radiance spectrum   (AR)
      to be plotted?
      Enter one of PT, XT, AT or AR :
AR
**Q** Curve   1. IATM no. of layer atmosphere? :
1
**Q** Curve   1. ILAY no. of layer to be plotted? :
24
**Q** Are wide mesh binned spectral values to be plotted? [Y/N] :
N
**Q** Enter line type and pen type for drawing curve LTYPE,IPEN :
1,2
**Q** Enter curve caption, 50 chars. max. :
Radiance from sea surface @ 282.44 K
##### CURVE NO.  2 #####
**Q** Is a path transmittance spectrum                    (PT),
      a mixed path transmittance spectrum                 (XT),
      a radiating atmosphere layer transmittance spectrum (AT),
      or a radiating atmosphere layer radiance spectrum   (AR)
      to be plotted?
      Enter one of PT, XT, AT or AR :
AR
**Q** Curve   2. IATM no. of layer atmosphere? :
2
**Q** Curve   2. ILAY no. of layer to be plotted? :
19
**Q** Are wide mesh binned spectral values to be plotted? [Y/N] :
N
**Q** Enter line type and pen type for drawing curve LTYPE,IPEN :
3,3
**Q** Enter curve caption, 50 chars. max. :
Radiance from 4.9 km cloud top @ 265 K
##### CURVE NO.  3 #####
**Q** Is a path transmittance spectrum                    (PT),
      a mixed path transmittance spectrum                 (XT),
      a radiating atmosphere layer transmittance spectrum (AT),
      or a radiating atmosphere layer radiance spectrum   (AR)
      to be plotted?
      Enter one of PT, XT, AT or AR :
AR
**Q** Curve   3. IATM no. of layer atmosphere? :
3
**Q** Curve   3. ILAY no. of layer to be plotted? :
13
**Q** Are wide mesh binned spectral values to be plotted? [Y/N] :
N
**Q** Enter line type and pen type for drawing curve LTYPE,IPEN :
4,4
**Q** Enter curve caption, 50 chars. max. :
Radiance from 10.4 km cloud top @ 224 K
**Q** Do you want to degrade the spectra with an
      instrument line shape (ILS) function? [Y/N] :
Y
**Q** ILS function type specifier;
      1 = square boxcar
      2 = triangle
      3 = Fourier spec. (only with evenly spaced points)
      4 = user supplied (only with evenly spaced points)
      Enter 1,2,3 or 4 :
2
**Q** Enter triangle half power band width in cm-1 :
0.5
**Q** Are all points to be plotted? [Y/N] :
N
**Q** Enter no of plot points/cm-1 :
50
**Q** Is an external spectra to be plotted? [Y/N] :
Y
**Q** Enter number of external spectra for plotting :
1
##### EXTERNAL SPECTRUM NO.  1 #####
**Q** Enter name of file containing spectrum data :
ex1_gengrp_res.dat
**Q** Enter line type and pen type for drawing curve LTYPE,IPEN :
2,1
**Q** Enter spectrum caption, 50 chars. max. :
AVHRR Channel 4
**Q** Enter spectrum plot Y-axis title :
RADIOMETER RESPONSE
```


GENLN2: RADIANCE SPECTRUM
LAYER BDY RADIANCE W/(m2.sr.cm-1)
.12
.11
.10
.09
.08
.07
.06
.05
.04
.03
.02
RADIOMETER RESPONSE
.013
.012
.011
.010
.009
.008
.007
.006
.005
.004
.003
.002
.001
0
860
880
900
920
940
960
980
1000
WAVENUMBER cm-1
Nadir example calculation: AVHRR Ch.4
Radiance from sea surface • 282.44 K
Radiance from 4.9 km cloud top • 265 K
Radiance from 10.4 km cloud top • 224 K
AVHRR Channel 4

```
!
! ************************************
! *  NOAA 9 AVHRR CHANNEL 4 RESPONSE  *
! *          Data is in ESDA          *
! ************************************
 'AVHRR'        4
    60         80.0
     1  8.62069E+02  0.00000E+00
     2  8.64447E+02  3.06030E-05
     3  8.66825E+02  6.45630E-05
     4  8.69203E+02  1.05230E-04
     5  8.71581E+02  1.70570E-04
     6  8.73959E+02  3.71390E-04
     7  8.76338E+02  8.54880E-04
     8  8.78716E+02  1.75260E-03
     9  8.81094E+02  2.99470E-03
    10  8.83472E+02  4.37180E-03
    11  8.85850E+02  5.67390E-03
    12  8.88228E+02  6.78440E-03
    13  8.90606E+02  7.71530E-03
    14  8.92984E+02  8.48510E-03
    15  8.95363E+02  9.12220E-03
    16  8.97741E+02  9.62980E-03
    17  9.00119E+02  1.00220E-02
    18  9.02497E+02  1.03100E-02
    19  9.04875E+02  1.05250E-02
    20  9.07253E+02  1.07080E-02
    21  9.09631E+02  1.09030E-02
    22  9.12009E+02  1.11300E-02
    23  9.14388E+02  1.13700E-02
    24  9.16766E+02  1.15960E-02
    25  9.19144E+02  1.17860E-02
    26  9.21522E+02  1.19490E-02
    27  9.23900E+02  1.21110E-02
    28  9.26278E+02  1.22990E-02
    29  9.28656E+02  1.25230E-02
    30  9.31034E+02  1.27460E-02
    31  9.33412E+02  1.29260E-02
    32  9.35791E+02  1.30220E-02
    33  9.38169E+02  1.30390E-02
    34  9.40547E+02  1.30300E-02
    35  9.42925E+02  1.30470E-02
    36  9.45303E+02  1.31350E-02
    37  9.47681E+02  1.32740E-02
    38  9.50059E+02  1.34190E-02
    39  9.52437E+02  1.35220E-02
    40  9.54816E+02  1.35180E-02
    41  9.57194E+02  1.32740E-02
    42  9.59572E+02  1.26400E-02
    43  9.61950E+02  1.14660E-02
    44  9.64328E+02  9.72390E-03
    45  9.66706E+02  7.66980E-03
    46  9.69084E+02  5.60310E-03
    47  9.71462E+02  3.82250E-03
    48  9.73841E+02  2.50390E-03
    49  9.76219E+02  1.58350E-03
    50  9.78597E+02  9.70020E-04
    51  9.80975E+02  5.71920E-04
    52  9.83353E+02  3.16260E-04
    53  9.85731E+02  1.66040E-04
    54  9.88109E+02  8.84220E-05
    55  9.90487E+02  5.06250E-05
    56  9.92865E+02  2.75940E-05
    57  9.95244E+02  1.34550E-05
    58  9.97622E+02  5.24550E-06
    59  1.00000E+03  5.31190E-10
    60  1.00238E+03  0.00000E+00
```

Ex.1. Nadir View: Program RADTEM

ex1_radtem_ip.dat


```
##############################################
##############################################
##            PROGRAM RADTEM                ##
##            --------------                ##
##  PROGRAM TO CALCULATE A RADIANCE TO      ##
##  EQUIVALENT BRIGHTNESS TEMPERATURE       ##
##  LOOK-UP TABLE FOR A GIVEN RADIOMETER    ##
##  WIDEBAND RESPONSE FUNCTION.             ##
##  VERSION 3.0   D.P. EDWARDS   27/02/91   ##
##  (C) COPYRIGHT 1991 UCAR/NCAR            ##
##  ALL RIGHTS RESERVED                     ##
##  GENLN2 SOFTWARE AND RELATED MATERIALS   ##
##  MAY BE USED ONLY UNDER AN EXECUTED      ##
##  VALID LICENCE AGREEMENT                 ##
##############################################
##############################################


**Q** Enter name of channel response data file :
ex1_gengrp_res.dat
**Q** Enter name of rad.--> bright.T. output look-up file :
ex1_radtem_op.dat
**Q** Enter the lower and upper temperatures [K] and
      no of temperature points per degree K:
150.0, 350.0, 10
**Q** Enter number of points for spectral integation :
200
```

```
! ************************************************
! ************************************************
! **  RADTEM: POST-PROCESSING PROGRAM FOR       **
! **  GENLN2. RADIANCE-->EQUIVALENT BRIGHTNESS  **
! **  TEMPERATURE ([W/(m2.sr.cm-1)]-->[K])      **
! **  CONVERSION LOOKUP TABLE                   **
! **  VERSION 3.0   D.P. EDWARDS   27/02/91     **
! **  (C) COPYRIGHT 1991 UCAR/NCAR              **
! **  ALL RIGHTS RESERVED                       **
! **  GENLN2 SOFTWARE AND RELATED MATERIALS     **
! **  MAY BE USED ONLY UNDER AN EXECUTED VALID  **
! **  LICENCE AGREEMENT                         **
! ************************************************
! ************************************************
!
! TEMPERATURES BETWEEN 150.0 AND 350.0 K IN   .100 K INTERVALS
! FILTER PROFILE TAKEN FROM:-
!
! ************************************
! *  NOAA 9 AVHRR CHANNEL 4 RESPONSE  *
! *          Data is in ESDA
! ************************************
! DATA FOR CHANNEL NO.  4
! FREQUENCY MESH FOR PLANCK FUNCTION CONVOLUTION   .705 cm-1.
!
  150.0    350.0      10
  150.000    1.299550E-03 1.307260E-03 1.315005E-03 1.322787E-03 1.330603E-03
             1.338456E-03 1.346345E-03 1.354269E-03 1.362230E-03 1.370226E-03
  151.000    1.378259E-03 1.386330E-03 1.394435E-03 1.402578E-03 1.410756E-03
             1.418973E-03 1.427227E-03 1.435516E-03 1.443844E-03 1.452208E-03
  152.000    1.460611E-03 1.469050E-03 1.477528E-03 1.486042E-03 1.494594E-03
             1.503186E-03 1.511815E-03 1.520481E-03 1.529187E-03 1.537930E-03
  153.000    1.546712E-03 1.555535E-03 1.564393E-03 1.573292E-03 1.582229E-03
             1.591205E-03 1.600221E-03 1.609275E-03 1.618370E-03 1.627503E-03
  154.000    1.636678E-03 1.645891E-03 1.655143E-03 1.664437E-03 1.673769E-03
             1.683143E-03 1.692557E-03 1.702010E-03 1.711505E-03 1.721039E-03
etc.

  340.000    1.909020E-01 1.911273E-01 1.913526E-01 1.915779E-01 1.918036E-01
             1.920293E-01 1.922552E-01 1.924812E-01 1.927073E-01 1.929336E-01
  341.000    1.931601E-01 1.933866E-01 1.936134E-01 1.938401E-01 1.940671E-01
             1.942942E-01 1.945214E-01 1.947489E-01 1.949764E-01 1.952040E-01
  342.000    1.954319E-01 1.956598E-01 1.958879E-01 1.961161E-01 1.963445E-01
             1.965730E-01 1.968017E-01 1.970304E-01 1.972593E-01 1.974883E-01
  343.000    1.977175E-01 1.979468E-01 1.981763E-01 1.984059E-01 1.986356E-01
             1.988655E-01 1.990955E-01 1.993257E-01 1.995559E-01 1.997864E-01
  344.000    2.000170E-01 2.002477E-01 2.004784E-01 2.007095E-01 2.009406E-01
             2.011718E-01 2.014033E-01 2.016347E-01 2.018663E-01 2.020982E-01
  345.000    2.023301E-01 2.025623E-01 2.027944E-01 2.030268E-01 2.032592E-01
             2.034919E-01 2.037247E-01 2.039575E-01 2.041905E-01 2.044237E-01
  346.000    2.046570E-01 2.048905E-01 2.051241E-01 2.053578E-01 2.055916E-01
             2.058256E-01 2.060598E-01 2.062940E-01 2.065283E-01 2.067629E-01
  347.000    2.069975E-01 2.072324E-01 2.074674E-01 2.077024E-01 2.079376E-01
             2.081731E-01 2.084085E-01 2.086441E-01 2.088799E-01 2.091158E-01
  348.000    2.093518E-01 2.095880E-01 2.098244E-01 2.100608E-01 2.102974E-01
             2.105342E-01 2.107709E-01 2.110080E-01 2.112451E-01 2.114823E-01
  349.000    2.117198E-01 2.119573E-01 2.121950E-01 2.124328E-01 2.126707E-01
             2.129088E-01 2.131471E-01 2.133854E-01 2.136239E-01 2.138626E-01
  350.000    2.141013E-01 2.143402E-01 2.145793E-01 2.148183E-01 2.150577E-01
             2.152972E-01 2.155368E-01 2.157765E-01 2.160162E-01 2.162562E-01
```

Ex.1. Nadir View: Program BRIGHT
ex1_bright_ip.dat


```
##################################################
##################################################
##            PROGRAM BRIGHT                    ##
##            --------------                    ##
##   POST-PROCESSING PROGRAM FOR GENLN2:        ##
##   CONVOLVES TRANSMITTANCES/RADIANCES WITH    ##
##   A RADIOMETER WIDEBAND RESPONSE FUNCTION    ##
##   AND OPTIONALLY CONVERTS TO EQUIVALENT      ##
##   BRIGHTNESS TEMPERATURE                     ##
##   VERSION 3.0   D.P. EDWARDS   27/02/91      ##
##   (C) COPYRIGHT 1991 UCAR/NCAR               ##
##   ALL RIGHTS RESERVED                        ##
##   GENLN2 SOFTWARE AND RELATED MATERIALS MAY  ##
##   BE USED ONLY UNDER AN EXECUTED VALID       ##
##   LICENCE AGREEMENT                          ##
##################################################
##################################################


**Q** Enter name of GENLN2 unformatted output file :
ex1_genln2_ops.dat
**Q** Are wide mesh binned spectral values to be used? [Y/N] :
Y
**Q** Enter name of channel response data file :
ex1_gengrp_res.dat
**Q** Are path transmittances to be convolved? [Y/N] :
N
**Q** Are mixed path transmittances to be convolved? [Y/N] :
N
**Q** Are layer transmittances to be convolved? [Y/N] :
N
**Q** Are layer radiances to be convolved? [Y/N] :
Y
**Q** Are brightness temps to be calculated?  [Y/N] :
Y
**Q** Enter name of rad.--> bright.T. look-up file :
ex1_radtem_op.dat
**Q** Enter name of output file :
ex1_bright_op.dat
```

Ex.1. Nadir View: Program BRIGHT

ex1_bright_op.dat


```
**************************************************
**************************************************
**  BRIGHT: POST-PROCESSING PROGRAM FOR         **
**  GENLN2. CONVOLVES TRANSMITTANCES/RADIANCES  **
**  WITH RADIOMETER WIDEBAND RESPONSE FUNCTION  **
**  AND OPTIONALLY CONVERTS TO EQUIVALENT       **
**  BRIGHTNESS TEMPERATURE                      **
**  VERSION 3.0   D.P. EDWARDS   27/02/91       **
**  (C) COPYRIGHT 1991 UCAR/NCAR                **
**  ALL RIGHTS RESERVED                         **
**  GENLN2 SOFTWARE AND RELATED MATERIALS MAY   **
**  BE USED ONLY UNDER AN EXECUTED VALID        **
**  LICENCE AGREEMENT                           **
**************************************************
**************************************************


GENLN2 OUTPUT DATA FILENAME   : ex1_genln2_ops.dat

FILTER RESPONSE DATA FILENAME: ex1_gengrp_res.dat

RADIANCE-->BT TABLE FILENAME : ex1_radtem_op.dat

TITLE OF GENLN2 RUN          : Nadir example calculation: AVHRR Ch.4


!
! ************************************
! *  NOAA 9 AVHRR CHANNEL 4 RESPONSE  *
! *          Data is in ESDA
! ************************************

CONVOLVED LAYER RADIANCES
*************************
```

ATMOSPHERE NO.	LAYER NO.	CONVOLVED RADIANCE [W/(cm-1.sr.m2)]	BRIGHTNESS TEMPERATURE [K]
1	24	9.72727E-02	290.819
2	19	6.17255E-02	264.807
3	13	2.86707E-02	229.983

APPENDIX 2. EXAMPLE CALCULATION 2: LIMB VIEW

A2.1 Overview of Example Calculation 2

Example calculation 2 is for a limb viewing geometry problem to reproduce a measurement from a high resolution satellite interferometer. The object is to calculate the transmittance spectrum for a narrow spectral region near the 720 cm^{-1} CO_2 Q-branch at a tangent height of 30 km. An emission calculation is also performed to separate the thermal emission of CO_2 and O_3.

A2.2 Program HITLIN

Line coupling will be included in this calculation so it is necessary to update the 1991 HITRAN database with the line data file, **co2mix.dat**, that includes the CO_2 lines that couple. These lines have the HITRAN REF parameter flagged to indicate that line coupling coefficients exist and will be included in the GENLN2 calculation. The lines from the HITRAN file are given status 10 and those from **co2mix.dat** are given status 11.

Lines are included over the spectral range 550 to 760 cm^{-1} to cover the CO_2 15 μm region. A binary line data file ex2_hitlin_op.dat for use by GENLN2 is created, with MACH=2 since the calculation is performed on the IBM. This file will also be used by the GENLN2 PMR calculations of Appendix 3. The input file **ex2_hitlin_ip.dat** should be assigned to FORTRAN unit 4 before execution.

A2.3 Program LAYERS

The LAYERS calculation layers the atmosphere using the *MODPRO option and the U.S. 1976 Standard atmosphere model profile (MONO=6) from the model atmosphere profile data set **glatm.dat**. An integration sub-layer accuracy of 10 is specified and because this is a limb viewing calculation, the refraction calculation is switched on. The lower and upper wavenumbers of the proposed calculation range are provided for use in the calculation of the refractive index of air. The *LEVELS option is used to switch on the printing of a summary of the layer structure.

The user defined layering option is used and 20 vertical atmospheric layers are defined starting at the tangent height of 30 km and finishing at 80 km. Notice that a narrow layer structure is used near the tangent height. A symmetric atmosphere is assumed here, i.e. the same layers will be used anterior and posterior to the tangent point as shown in Fig.A2.1. Two gases, CO_2 and O_3 are included in each layer. The CO_2 line shape with continuum is specified for use with CO_2 in the GENLN2 calculation. The Voigt line shape will be used for O_3. The ray paths are launched from the tangent point at a local zenith angle of 90° and the ray tracing calculation defines curved paths in each concentric layer. The geometry of each path is defined by Fig.3.2 and the angle parameters are output for each path in **ex2_layers_op.dat**.

The input file **ex2_layers_ip.dat** and the output path file **ex2_layers_op.dat** should be assigned to FORTRAN units 4 and 30 respectively before execution.

This calculation produces a 20 layer atmosphere with each layer containing 2 gases. There are 40 paths in total, paths 1–20 are for CO_2 in layers 1–20, and paths 21–40 are for O_3 in layers 1–20. The output file, **ex2_layers_op.dat**, is used as the input to the *PTHFIL input stage of GENLN2. This file will also be used by the GENLN2 PMR calculations of Appendix 3.

A2.4 Program GENLN2

The line data file produced by HITLIN, **ex2_hitlin_op.dat**, is used when performing the line-by-line calculation for CO_2 and O_3. Line coupling is included in the calculation by setting LCHOSE=11 for CO_2 so that the status 11 line parameters, i.e. those lines involved in coupling from file **co2mix.dat**, are used when they appear on the line file in preference to status 10 HITRAN lines. HITRAN status 10 lines are used for O_3.

A default, *DEFGRD, wavenumber grid is used and 25 cm^{-1} are allowed for line wings either side of the pass-band range of 718–722 cm^{-1}. The wide mesh interval DELTA is set at $1cm^{-1}$. In the *SPECTM section FEXC=1 cm^{-1}, and because a continuum calculation will be included FWIND=25 cm^{-1}. With NDIV=4000 a fine wavenumber grid spacing of 0.00025 cm^{-1} is produced.

The path data is read in the *PTHFIL input section from the output file of LAYERS, **ex2_layers_op.dat**. The mixing table defines 20 mixed paths as shown in Fig.A2.1. Mixed path 1 is made up of path 1 (CO_2 in layer 1), path 21 (O_3 in layer 1), mixed path 2 is made up of path 2 (CO_2 in layer 2), path 22 (O_3 in layer 2), etc. These mixed paths will be used in the radiance calculations to define the total optical depth due to all gases in each layer of the atmosphere.

Three radiating atmosphere calculations are performed. The viewing parameter IVIEW=1 defines limb views with no initiating boundary condition. For the first two calculations the layer emission parameter IEMS=2 to signify that emission calculations are being performed. The first radiating atmosphere is for a CO_2 emission calculation. The optical depths of the layers for absorption are first defined in terms of mixed paths, LAYSP=2. The 40 layers of the atmosphere in absorption are defined from space to the tangent point, down from mixed path 20 to mixed path 1, and then back to space, up from mixed path 1 to mixed path 20. The optical depths of the layers for emission are then defined in terms of CO_2 paths, LEMSP=1. The 40 layers of the atmosphere in emission are defined from space to the tangent point, down from path 20 to path 1, and then back to space, up from path 1 to path 20.

The second radiating atmosphere is for an O_3 emission calculation. This is the same as the first radiating atmosphere but now the 40 layers of the atmosphere in emission are defined in terms of O_3 paths; from space to the tangent point, down from path 40 to path 21, and then back to space, up from path 21 to path 40.

In the third radiating atmosphere the layer emission parameter IEMS=1 and an emission calculation is not performed. In this case the same set of mixed path optical depths (20 down to 1 at the tangent point, and then 1 to 20 back to space) are used to define the atmosphere in both absorption and emission, therefore giving the total radiance. All the radiance calculations define atmospheres of 40 layers, with the interferometer situated at the furthest boundary of layer 40.

The *INTEGN section is included so the spectra will be binned and averaged over the width of the wide mesh intervals. Selection of the spectra to be output is made in in the *OUTPUT section. The point transmittance IDAT=5, and radiance spectra IDAT=7, at layer 40 are selected for each of the radiating atmosphere calculations.

A listing is given of the formatted summary output data file. This gives a summary of the GENLN2 input to the calculation together with the integrated spectra specified for output in *TITLES. The input file, **ex2_genln2_ip.dat**, and the formatted summary output data file, **ex2_genln2_opd.dat**, should be assigned to FORTRAN units 4 and 30 respectively before execution.

A2.5 Program GENGRP

The input dialogues and plots for two runs of GENGRP are listed. The first plot, **ex2_gengrp_rad.dat**, shows separately the CO_2 and O_3 emission of the limb path, with each attenuated by the combined gas absorption. The spectra are degraded assuming an interferometer of resolution 0.01 cm^{-1}, i.e. a maximum optical retardation length of 50 cm. The spectra have also been apodized using a medium apodizing function.

The second plot, **ex2_gengrp_trans.dat**, shows the total transmittance of the limb path. The spectrum has also been degraded and apodized assuming the interferometer of resolution 0.01 cm^{-1}.

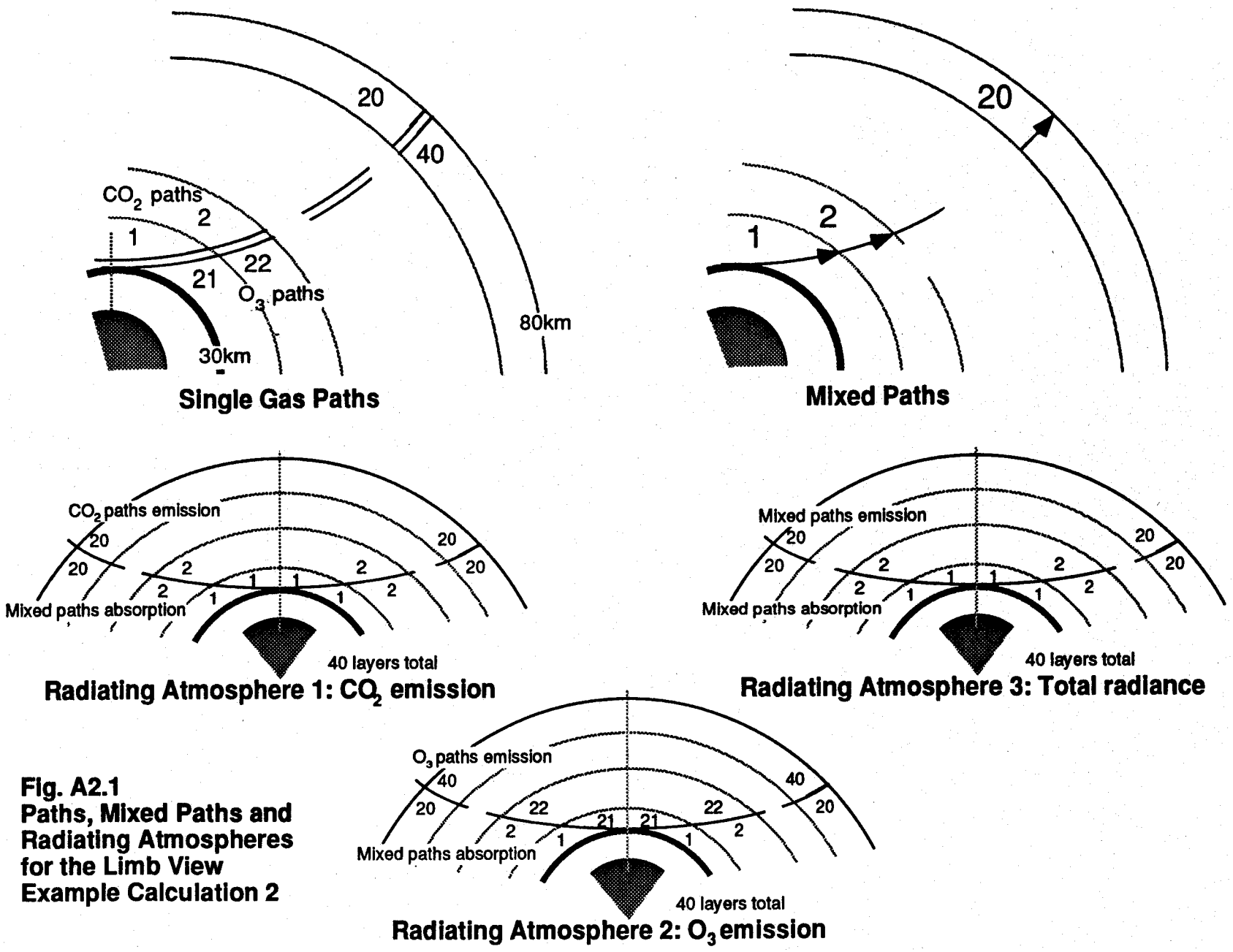


Fig. A2.1
Paths, Mixed Paths and Radiating Atmospheres for the Limb View Example Calculation 2

```
!
!
!           ***********************************************
!           *                                             *
!           *         PROGRAM HITLIN: INPUT FILE          *
!           *         --------------------------          *
!           *  PROGRAM TO CREATE A BINARY LINE DATA BASE  *
!           *  FROM ONE OR MORE LINE DATA FILES IN THE    *
!           *  HITRAN FORMAT. THE BINARY FILE IS IN THE   *
!           *  REQUIRED FORM FOR GENLN2.                  *
!           *  VERSION 3.0:  D.P. EDWARDS 26/03/90        *
!           *                                             *
!           ***********************************************
!                                                    INPUT PARAMETER NAME
!-----------------------------------------------------------------------------
!..TITLE LABEL FOR THIS HITLIN RUN (*TITLES) [MANDATORY]
*TITLES
!
!  1A. Title label of this HITLIN run :                                AHEAD
'Limb example calculation'
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..LINE DATA FILES (*LINDAT) [MANDATORY]
*LINDAT
!
!  1A. No of formatted line data files (HITRAN format)                 NFIL
2
!
!  For each line data file, 1 record (IFIL=1,NFIL)
!  2A. Status number for lines on file IFIL:                     NEWST(IFIL)
!  2B. Filename of line data file:                                FNIN(IFIL)
10, 'hitran91.asc'
11, 'co2mix.dat'
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..FREQUENCY RANGE FOR OUTPUT (*RANGES) [MANDATORY]
*RANGES
!
!  1A. Maximum number of different gases on output file:               NGAS
!  1B. Lowest wavenumber for output file:                               WN1
!  1C. Highest wavenumber for output file:                              WN2
35, 550.0, 760.0
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..OUTPUT FILE (*OUTPUT) [MANDATORY]
*OUTPUT
!
!  1.A File name of the binary output line file to be used by GENLN2:  FNOUT
'ex2_hitlin_op.dat'
!
!  2.A Machine specifier, determines record length:
!      MACH=1: 4 byte/word machine, OPEN RECL in words (eg. VAX, ANSII stand)
!      MACH=2: 4 byte/word machine, OPEN RECL in bytes (eg. IBM RISC)
!      MACH=3: 8 byte/word machine, OPEN RECL in bytes (eg. CRAY)
2
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..END OF HITLIN INPUT (*ENDINP) [MANDATORY]
*ENDINP
!!!!!!!! End of section !!!!!!!
```

```
!
!
!          ************************************************
!          *                                              *
!          *            PROGRAM LAYERS: INPUT FILE        *
!          *            --------------------------        *
!          *  GENLN2 PATH PRE-PROCESSING PROGRAM. PERFORMS *
!          *  ATMOSPHERIC LAYERING AND CALCULATES CURTIS  *
!          *  --GODSON ABSORBER WEIGHTED MEAN PATH        *
!          *  PARAMETERS. OUTPUT PATH FILE IS IN THE FORMAT *
!          *  REQUIRED FOR DIRECT INPUT TO GENLN2.        *
!          *  VERSION 3.0: D.P. EDWARDS 01/08/90          *
!          *                                              *
!          ************************************************
!                                                INPUT PARAMETER NAME
!-----------------------------------------------------------------------
!..TITLE INFORMATION FOR THIS LAYERS RUN (*TITLES) [MANDATORY]
*TITLES
!
!  1A. Title of this LAYERS run (80 characters max):                TITLEP
'Limb example calculation'
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------
!..MODEL PROFILE (*MODPRO) [MANDATORY if *USEPRO is not supplied]
*MODPRO
!
!  1A. Filename of model profile data set to be used (80 characters max): FNAFGL
'glatm.dat'
!  2A. Number of model profile to be used :                          MONO
!      1. Tropical            2. Midlatiude Summer
!      3. Midlatitude Winter  4. Subarctic Summer
!      5. Subarctic Winter    6. U.S. Standard
6
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------
!..INTEGRATION PARAMETERS (*SUBLAY) [MANDATORY]
*SUBLAY
!
!  1A. Integration sub-layer accuracy :                              NP
!  1B. Refraction switch :                                         LREF
10,   .TRUE.
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------
!..FREQUENCY PARAMETERS (*FREQCY) [MANDATORY]
*FREQCY
!
!  1.A Lower wavenumber bound of proposed GENLN2 calculation :       V1
!  1.B Upper wavenumber bound of proposed GENLN2 calculation :       V2
718.0, 722.0
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------
!..PRINT SWITCH (*LEVELS) [NOT MANDATORY]
*LEVELS
!
!  This section sets a logical flag that causes extra data about
!  the level height structure to be output. This might be used
!  later in the input to a weighting function calcultion.
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------
!..USER SUPPLIED LAYERS (*USELAY) [MANDATORY if *DEFLAY are not supplied]
*USELAY
!
!  1.A Layer boundaries at height ('H') or pressure ('P') levels:    COOR
!  1.B Number of layers for calculation :                           NOLAY
!  1.C Number of different path gases in each layer :                NOGAS
'H', 20, 2
!
!  For each different layer path gas (IG=1,NOGAS) 1 input record
!  2.A Line file no to be used in output file for paths of this gas :  IFILE(IG)
!  2.B Molecular ID of gas :                                         LISTG(IG)
!  2.C Isotope ID of gas :                                           LISTI(IG)
!  2.D Line shape character string (8 Char.) to be used in
!      output file for paths of this gas :                          SHAPE(IG)
!  2.E Continuum character string specifier 'CON     ' or 'NOCON'
!      to be used in output file for paths of this gas :             CNTM(IG)
!  2.F Layer number to be used in defining Snell's Law
!      constant= n(r)*r*sin(theta) for paths of this gas :          MLANG(IG)
!  2.G Ray initial zenith angle (theta) for layer MLANG(IG)  :     THETAL(IG)
1, 2, 0, 'VOIGTCO2', 'CON  ', 1, 90.0
1, 3, 0, 'VOIGT',    'NOCON', 1, 90.0
!
!  For each layer (ILAY=1,NOLAY) 1 input record
!  3.A Layer number :                                                ILAY
!  3.B Layer lower boundary (km if COOR='H' or mb if COOR='P') :   XLL(ILAY)
!  3.C Layer upper boundary (km if COOR='H' or mb if COOR='P') :   XLU(ILAY)
!
 1     30.0  30.5
 2     30.5  31.0
 3     31.0  32.0
 4     32.0  33.0
 5     33.0  34.0
 6     34.0  35.0
 7     35.0  36.0
 8     36.0  37.0
 9     37.0  38.0
10     38.0  40.0
11     40.0  42.0
12     42.0  44.0
13     44.0  46.0
14     46.0  48.0
15     48.0  50.0
16     50.0  55.0
17     55.0  60.0
18     60.0  65.0
19     65.0  70.0
20     70.0  80.0
!!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------
!..END OF LAYERS INPUT (*ENDINP) [MANDATORY]
*ENDINP
!!!!!!!! End of section !!!!!!!
```

Ex.2. Limb View: Program LAYERS

ex2_layers_op.dat


```
! ***********************************************
! ***********************************************
! **  LAYERS: GENLN2 PATH PRE-PROCESSING        **
! **  ATMOSPHERIC LAYERING AND PATH GAS CURTIS  **
! **  GODSON CALCULATION                        **
! **  VERSION 3.0   D.P. EDWARDS   27/02/91     **
! **  (C) COPYRIGHT 1991 UCAR/NCAR              **
! **  ALL RIGHTS RESERVED                       **
! **  GENLN2 SOFTWARE AND RELATED MATERIALS MAY **
! **  BE USED ONLY UNDER AN EXECUTED VALID      **
! **  LICENCE AGREEMENT                         **
! ***********************************************
! ***********************************************
!
!
! TITLE OF THIS LAYERS RUN:
! Limb example calculation
!
! AFGL MODEL USED: 6. U.S. Standard
!
! LAYER HEIGHTS DEFINED FOR USE WITH ALL GASES.
!
! ATMOSPHERIC REFRACTION INCLUDED.
!
! INTEGRATION ACCURACY CRITERION PARAMETER =  10
!
! TOTAL NO. OF PATHS CALCULATED:
  40
!
! PATH   1 ** CO2 ** HEIGHTS:  30.000 -  30.500 km, 1.197E+01 - 1.105E+01 mb.
! RAY LENGTH =  80.1632 km, THETA = 9.0000E+01.
! PHI =  .9071E+02, BETA =  .7182E+00, BEND =  .3137E-02 deg.
  1,  2, 0,        1.6368E-06,  226.728,  1.1511E-02,  3.7987E-06,   0.0
'VOIGTCO2'  'CON     '
! PATH   2 ** CO2 ** HEIGHTS:  30.500 -  31.000 km, 1.105E+01 - 1.019E+01 mb.
! RAY LENGTH =  33.1990 km, THETA = 8.9285E+01.
! PHI =  .9101E+02, BETA =  .2976E+00, BEND =  .1182E-02 deg.
  1,  2, 0,        6.1648E-07,  227.525,  1.0505E-02,  3.4666E-06,   0.0
'VOIGTCO2'  'CON     '
etc.

! PATH  20 ** CO2 ** HEIGHTS:  70.000 -  80.000 km, 5.220E-02 - 1.050E-02 mb.
! RAY LENGTH =  84.9106 km, THETA = 8.3612E+01.
! PHI =  .9714E+02, BETA =  .7502E+00, BEND =  .7202E-05 deg.
  1,  2, 0,        4.2534E-09,  211.467,  3.1263E-05,  1.0313E-08,   0.0
'VOIGTCO2'  'CON     '
! PATH  21 ** O3 *** HEIGHTS:  30.000 -  30.500 km, 1.197E+01 - 1.105E+01 mb.
! RAY LENGTH =  80.1632 km, THETA = 9.0000E+01.
! PHI =  .9071E+02, BETA =  .7182E+00, BEND =  .3137E-02 deg.
  1,  3, 0,        3.2769E-08,  226.730,  1.1509E-02,  7.6093E-08,   0.0
'VOIGT   '  'NOCON   '
! PATH  22 ** O3 *** HEIGHTS:  30.500 -  31.000 km, 1.105E+01 - 1.019E+01 mb.
! RAY LENGTH =  33.1990 km, THETA = 8.9285E+01.
! PHI =  .9101E+02, BETA =  .2976E+00, BEND =  .1182E-02 deg.
  1,  3, 0,        1.2691E-08,  227.527,  1.0503E-02,  7.1554E-08,   0.0
'VOIGT   '  'NOCON   '
etc.

! PATH  39 ** O3 *** HEIGHTS:  65.000 -  70.000 km, 1.090E-01 - 5.220E-02 mb.
! RAY LENGTH =  46.4235 km, THETA = 8.4023E+01.
! PHI =  .9639E+02, BETA =  .4113E+00, BEND =  .9704E-05 deg.
  1,  3, 0,        9.9901E-12,  228.137,  8.3072E-05,  5.1213E-11,   0.0
'VOIGT   '  'NOCON   '
! PATH  40 ** O3 *** HEIGHTS:  70.000 -  80.000 km, 5.220E-02 - 1.050E-02 mb.
! RAY LENGTH =  84.9106 km, THETA = 8.3612E+01.
! PHI =  .9714E+02, BETA =  .7502E+00, BEND =  .7202E-05 deg.
  1,  3, 0,        3.5625E-12,  211.583,  3.1579E-05,  8.8820E-12,   0.0
'VOIGT   '  'NOCON   '
!
!
!  PATHS    1 --   20
!  GAS ID  2 ** CO2 **
!  TOTAL GAS COLUMN AMOUNT  [kg.moles/cm2] = 5.3863E-06
!  TOTAL RAY PATH LENGTH              [km] =    802.268
!  TOTAL EARTH CENTRED BENDING ANGLE [deg] = 7.1544E+00
!  TOTAL RAY PATH BENDING ANGLE      [deg] = 9.7558E-03
!
!  PATHS   21 --   40
!  GAS ID  3 ** O3 ***
!  TOTAL GAS COLUMN AMOUNT  [kg.moles/cm2] = 1.1235E-07
!  TOTAL RAY PATH LENGTH              [km] =    802.268
!  TOTAL EARTH CENTRED BENDING ANGLE [deg] = 7.1544E+00
!  TOTAL RAY PATH BENDING ANGLE      [deg] = 9.7558E-03
!
! ##################################################
! LAYER       H1        H2   DELTAH   DELTAX      dX/dH
! ---------------------------------------------------
!    20
!     1   30.000   30.500     .500   80.163  1.603E+02
!     2   30.500   31.000     .500   33.199  6.640E+01
!     3   31.000   32.000    1.000   46.957  4.696E+01
!     4   32.000   33.000    1.000   36.027  3.603E+01
!     5   33.000   34.000    1.000   30.371  3.037E+01
!     6   34.000   35.000    1.000   26.757  2.676E+01
!     7   35.000   36.000    1.000   24.191  2.419E+01
!     8   36.000   37.000    1.000   22.246  2.225E+01
!     9   37.000   38.000    1.000   20.706  2.071E+01
!    10   38.000   40.000    2.000   37.846  1.892E+01
!    11   40.000   42.000    2.000   34.219  1.711E+01
!    12   42.000   44.000    2.000   31.471  1.574E+01
!    13   44.000   46.000    2.000   29.297  1.465E+01
!    14   46.000   48.000    2.000   27.521  1.376E+01
!    15   48.000   50.000    2.000   26.034  1.302E+01
!    16   50.000   55.000    5.000   59.901  1.198E+01
!    17   55.000   60.000    5.000   54.181  1.084E+01
!    18   60.000   65.000    5.000   49.850  9.970E+00
!    19   65.000   70.000    5.000   46.424  9.285E+00
!    20   70.000   80.000   10.000   84.911  8.491E+00
```

Ex.2. Limb View: Program GENLN2

ex2_genln2_ip.dat


```
!                    ******************************************
!                    *                                        *
!                    *          PROGRAM GENLN2: INPUT FILE    *
!                    *          --------------------------    *
!                    *  INPUT FILE FOR THE GENLN2 LINE-BY-LINE *
!                    *  COMPUTER MODEL. CALCULATES ATMOSPHERIC *
!                    *  TRANSMITTANCE AND RADIANCE.            *
!                    *  VERSION 3.0: D.P. EDWARDS 21/08/90     *
!                    *                                        *
!                    ******************************************
!                                                    INPUT PARAMETER NAME
!-----------------------------------------------------------------------------
!..TITLE INFOMATION AND SUMMARY OUTPUT SPECIFICATION FOR THIS GENLN2 RUN
!..(*TITLES) [MANDATORY]
*TITLES
!
!      1A. Title of this GENLN2 run (40 characters MAX) :                TITLE
'Limb example calculation'
!
!      2A. Passband average spectral values only are printed in
!          formatted summary output file if logical is set true:         AVER
!      2B. Mixing table not printed if logical is set true:              MXER
.FALSE., .TRUE.
!
!      Data to be printed in the formatted summary output file is
!      specified by the IDAT parameter for the following categories:-
!      IDAT = 1  Path integrated transmittance spectrum.
!           = 2  Mixed path integrated transmittance spectrum.
!           = 3  Radiating atmosphere layer integrated
!                transmittance and radiance spectra.
!      The following section is repeated for each required IDAT.
!----------
!      3A. Index (1,2 or 3 above):                                       IDAT
3
!
!      If  IDAT = 1 or IDAT = 2:
!      4A. No. of paths or mixed paths to be printed: NP;
!          if all paths are to be print set NP<0.
!      Else if IDAT=3:
!      4A. Atmosphere no. for printing:                                  IATM
!          if all atmospheres are to be printed set IATM<0.
!      4B. no. of layers to be printed:                                  NP
!          if all layers are to be printed set NP<0.
-1, 1
!
!      For all IDAT:
!      5A. List of path, mixed path or layer nos. for printing;
!          only required if NP>0:                  (IOPDT(IDAT,IATM,I),I=1,NP)
40
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..THE GAS LINE DATA FILE(S) TO BE USED (*GASFIL) [MANDATORY]
*GASFIL
!
!      1A. No. of line data files to be read:                            NFILE
!      1B. Machine specifier, determines record length:                  MACH
!          MACH=1: 4 byte/word, OPEN RECL in words (eg. VAX, ANSII stand)
!          MACH=2: 4 byte/word, OPEN RECL in bytes (eg. IBM RISC)
!          MACH=3: 8 byte/word, OPEN RECL in bytes (eg. CRAY)
!          This should be the same as was used in HITLIN
1,2
!
!      For each file (IFILE=1,NFILE) 4 input records
!----------
!      2A. Filename of line data file:                                   FNAM(IFILE)
'ex2_hitlin_op.dat'
!
!      3A. No. of gases to be read from this file:                       NGAS(IFILE)
2
!
!      4A. Molecular ID's of the gas(es) to be read:
!                                        (LGASES(IFILE,IGAS),IGAS=1,NGAS(IFILE))
2, 3
!
!      5A. Line data version(s) to be chosen:
!                                        (LCHOSE(IFILE,IGAS),IGAS=1,NGAS(IFILE))
11, 10
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..LINE COUPLING CALCULATION FOR FLAGGED LINES ON THE DATABASE (*LINMIX)
!..[NOT MANDATORY]
*LINMIX
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..DEFAULT CALCULATION OF WIDE MESH BOUNDARY WAVENUMBER GRID (*DEFGRD)
!..[MANDATORY if one of *USEGRD, *GRDFIL or *RADIOM is not supplied]
*DEFGRD
!
!      1A. The minimum wavenumber to be considered (cm-1):               FMIN
!      1B. the lower integration (passband) wavenumber (cm-1):           FPSL
!      1C. the upper integration (passband) wavenumber (cm-1):           FPSU
!      1D. the maximum wavenumber to be considered (cm-1):               FMAX
!      1E. the wide mesh constant wavenumber interval spacing (cm-1):    DELTA
693.0, 718.0, 722.0, 747.0, 1.0
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..PARAMETERS DEFINING THE SPECTRAL CALCULATION REGIONS (*SPECTM)
!..[MANDATORY with *USEGRD, *GRDFIL or *DEFGRD.
!..Must not appear if *RADIOM is supplied]
*SPECTM
!      1A. The wavenumber range either side of a wide mesh interval for
!          which a fine grid line-by-line calculation is performed (cm-1):  FEXC
!      1B. the wavenumber range either side of the current interval
!          outside of which lines are not considered (cm-1):             FWIND
!      1C. the parameter specifying the division of the wide mesh
!          wavenumber interval to produce the fine mesh wavenumber grid:  NDIV
1.0, 25.0, 4000
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..PATH PARAMETERS READ FROM EXTERNAL FILE, EG. LAYERS OUTPUT FILE (*PTHFIL)
*PTHFIL
!
!      1A. File name of external path parameter file:                    PFNAM
'ex2_layers_op.dat'
!
!      File PFNAM then contains the same information as the
!      *PTHPAR section beginning with input record 2
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..MIXING PATHS TO FORM ATMOSPHERIC MIXED PATHS (*MIXING) [NOT MANDATORY]
*MIXING
!
!      1A. No. of mixed paths to be calculated:                          NPMIX
20
!
!      Mixing table is of length NPATH and depth NPMIX:
!      (remember NPATH is the sum of the number of paths read
!      in the *PTHPAR and the *PTHFIL sections)
```

```
!       The required mixing table parameters are:-
!       2A. The mixed path index:                                          IPMIX
!       2B. the mixing table:                  (TABMIX(IPATH,IPMIX),IPATH=1,NPATH))
!       Each new mixed path must begin a new line, and the
!       input field must not exceed 130 characters.
!
  1  ROT0    1 ROT19  ROT0    1 ROT19
  2  ROT1    1 ROT18  ROT1    1 ROT18
  3  ROT2    1 ROT17  ROT2    1 ROT17
  4  ROT3    1 ROT16  ROT3    1 ROT16
  5  ROT4    1 ROT15  ROT4    1 ROT15
  6  ROT5    1 ROT14  ROT5    1 ROT14
  7  ROT6    1 ROT13  ROT6    1 ROT13
  8  ROT7    1 ROT12  ROT7    1 ROT12
  9  ROT8    1 ROT11  ROT8    1 ROT11
 10  ROT9    1 ROT10  ROT9    1 ROT10
 11  ROT10   1 ROT9   ROT10   1 ROT9
 12  ROT11   1 ROT8   ROT11   1 ROT8
 13  ROT12   1 ROT7   ROT12   1 ROT7
 14  ROT13   1 ROT6   ROT13   1 ROT6
 15  ROT14   1 ROT5   ROT14   1 ROT5
 16  ROT15   1 ROT4   ROT15   1 ROT4
 17  ROT16   1 ROT3   ROT16   1 ROT3
 18  ROT17   1 ROT2   ROT17   1 ROT2
 19  ROT18   1 ROT1   ROT18   1 ROT1
 20  ROT19   1 ROT0   ROT19   1 ROT0
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..RADIANCE CALCULATION (*RADNCE) [NOT MANDATORY]
*RADNCE
!
!       1A. No. of radiating atmospheres to be calculated:                 NATM
3
!       For each atmosphere (IATM=1,NATM) 3 input records
!----------
!       Layer table data consists of the following:-
!       2A. The radiating atmosphere index:                                IATM
!       2B. the viewing parameter:                                   IVIEW(IATM)
!       2C. the layer emission parameter:                             IEMS(IATM)
!       2D. the no. of layers in the atmosphere:                      NLAY(IATM)
!       2E. path or mixed path specifer for total layer absorption:  LAYSP(IATM)
!       2F. the path (LAYSP(IATM)=1) or mixed path nos.(LAYSP(IATM)=2)
!           to be used to specify the layer total absorption in order
!           of radiation travel:          (LAYER(ILAY,IATM),ILAY=1,NLAY(IATM))
1, 1, 2, 40, 2
20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
!
!       If IVIEW(IATM)=2 then the initiating surface parameters are supplied:
!       3A. Atmospheric boundary temperature (K):                    TBDY(IATM)
!       3B. temperature of the initiating surface:                  TINIT(IATM)
!       3C. emissivity of initiating surface:                       EMSTY(IATM)
!TBDY(1), TINIT(1), EMSTY(1)
!
!       If IEMS(IATM)=2 different paths/mixed paths can to be used for
!       layer emission to those used for layer transmittance:
!       4A. path or mixed path specifer for emission layer absorption:LEMSP(IATM)
!       4B. the path (LEMSP(IATM)=1) or mixed-path nos.(LEMSP(IATM)=2)
!           to be used to specify the layer emission in order
!           in order of radiation travel:   (LAYEMS(ILAY,IATM),ILAY=1,NLAY(IATM))
1
20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
!----------
2, 1, 2, 40, 2
20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
1
40 39 38 37 36 35 34 33 32 31 30 29 28 27 26 25 24 23 22 21
21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40
!----------
3, 1, 1, 40, 2
20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..INTEGRATION SWITCH (*INTEGN) [NOT MANDATORY]
*INTEGN
!       Logical switch. When present the transmittance and radiance
!       spectra are integrated over each wide mesh interval.
!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..UNFORMATTED OUTPUT FILE SPECIFICATION (*OUTPUT) [NOT MANDATORY]
*OUTPUT
!
!       1A. File name of output file:                                     OPFNAM
'ex2_genln2_ops.dat'
!
!       Data to be output is specified by IDAT parameter
!       for the following categories:-
!       IDAT= 1  Path point transmission spectrum;
!           = 2  Path integrated transmission spectrum;
!           = 3  Mixed path point transmission spectrum;
!           = 4  Mixed path integrated transmission spectrum;
!           = 5  Layer point transmission spectrum;
!           = 6  Layer integrated transmission spectrum;
!           = 7  Layer point radiance spectrum;
!           = 8  Layer integrated radiance spectrum.
!       The following section is repeated for each required IDAT.
!----------
!       2A. Index (1 thro' 8 above):                                      IDAT
5
!
!       For IDAT = 1, 2, 3 or 4:
!       3A. no. of paths or mixed paths to be output:                       NP
!           if all paths are to be output set NP<0.
!       For IDAT = 5, 6, 7 or 8:
!       3A. atmosphere no. for output:                                    IATM
!           if all atmospheres are to be output set IATM<0.
!       3B. no. of layers to be output:                                     NP
!           if all layers are to be output set NP<0.
-1,1
!
!       For all IDAT:
!       4A. List of path, mixed path or layer nos. for output;
!           only required if NP>0:                  (IOPGR(IDAT,IATM,I),I=1,NP)
40
!----------
7
-1,1
40
!----------
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..END OF GENLN2 INPUT (*ENDINP) [MANDATORY]
*ENDINP
!!!!!!! End of input data to GENLN2 !!!!!!!
```

```
************************************************
************************************************
**  GENLN2: GENERAL LINE-BY-LINE ATMOSPHERIC  **
**  TRANSMITTANCE AND RADIANCE MODEL          **
**  VERSION 3.0   D.P. EDWARDS   27/02/91     **
**  (C) COPYRIGHT 1991 UCAR/NCAR              **
**  ALL RIGHTS RESERVED                       **
**  GENLN2 SOFTWARE AND RELATED MATERIALS     **
**  MAY BE USED ONLY UNDER AN EXECUTED VALID  **
**  LICENCE AGREEMENT                         **
************************************************
************************************************



DATE (DAY.MON.YR): 10.12.91


*************** CHECK INPUT DATA FOR ERRORS ***************

&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&


*************** INPUT DATA SUCCESSFULLY READ ***************

*************** SUMMARY OF INPUT DATA ***************

TITLE OF THIS RUN :- Limb example calculation

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

LINE AND CROSS-SECTION DATA
***************************
 1 LINE DATA FILE(S) WILL BE USED
FILE NO.  1 FILENAME ex2_hitlin_op.dat
 2 GAS(ES) TO BE READ, MOLEC ID NO(S):-     2    3
GAS LINE VERSION(S) TO BE CHOSEN:-         11   10
LINE MIXING SWITCHED ON
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

WAVENUMBER GRID
***************
TOTAL WAVENUMBER RANGE CONSIDERED         693.000 -     747.000 cm-1
PASSBAND (INTEGRATION) WAVENUMBER RANGE   718.000 -     722.000 cm-1
THIS CONSISTS OF     4 INTERVALS OF AVERAGE WAVENUMBER WIDTH      1.000 cm-1
EACH INTERVAL WILL BE DIVIDED INTO   4000 FINE MESHES FOR THE TRANSMITTANCE CALCULATION.
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

TRANSMITTANCE CALCULATION
*************************
THE LINE ABSORPTION IN A RANGE OF   1.000 cm-1 EITHER SIDE OF THE WIDEMESH INTERVAL WILL BE TREATED EXPLICITLY.
THE WING ABSORPTION DUE TO LINES LYING IN THE RANGE    1.000 -    25.000 cm-1
EITHER SIDE OF THE WIDEMESH INTERVAL WILL BE INCLUDED.
THE CONTINUUM ABSORPTION WILL BE INCLUDED FOR APPROPRIATE PATHS.
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

PATH DATA
*********
```

ex2_genln2_opd.dat

```
 PATH  FILE  GAS ID  ISO ID  AMT kg.moles/cm2      T K       P atm  PARTP atm     VEL m/s  LINESHAPE  CONTINUUM
------------------------------------------------------------------------------------------------------------------
    1     1       2       0        1.637E-06  226.728  1.151E-02  3.799E-06  0.000E+00   VOIGTCO2   CON
    2     1       2       0        6.165E-07  227.525  1.051E-02  3.467E-06  0.000E+00   VOIGTCO2   CON
    3     1       2       0        7.719E-07  228.541  9.357E-03  3.088E-06  0.000E+00   VOIGTCO2   CON
etc.

   37     1       3       0        1.192E-10  255.225  3.262E-04  5.231E-10  0.000E+00   VOIGT      NOCON
   38     1       3       0        3.643E-11  241.444  1.659E-04  1.635E-10  0.000E+00   VOIGT      NOCON
   39     1       3       0        9.990E-12  228.137  8.307E-05  5.121E-11  0.000E+00   VOIGT      NOCON
   40     1       3       0        3.562E-12  211.583  3.158E-05  8.882E-12  0.000E+00   VOIGT      NOCON
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

 MIXING TABLE DATA
 *****************
 MIXING TABLE IS OF LENGTH  40 PATH(S) AND DEPTH  20 MIXED PATH(S)

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

 RADIANCE DATA
 *************
 CALCULATIONS WILL BE PERFORMED FOR    3 RADIATING ATMOSPHERE(S)

 ATMOSPHERE  NO LAY  PTH/MIX   PATH/MIXED PATH NOS TO BE USED FOR LAYER TRANSMITTANCE IN ORDER OF THE DIRECTION OF RADIATION TRAVEL
 ------------------------------------------------------------------------------------------------------------------------------------

          1      40        2     20  19  18  17  16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1   1   2   3   4   5
                                  6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
 VIEWING  PARAMETER =  1
 EMISSION PARAMETER =  2       PATH/MIXED PATH NOS TO BE USED FOR LAYER EMISSION IN ORDER OF THE DIRECTION OF RADIATION TRAVEL
                               -----------------------------------------------------------------------------------------------------
                           1     20  19  18  17  16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1   1   2   3   4   5
                                  6   7   8   9  10  11  12  13  14  15  16  17  18  19  20

          2      40        2     20  19  18  17  16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1   1   2   3   4   5
                                  6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
 VIEWING  PARAMETER =  1
 EMISSION PARAMETER =  2       PATH/MIXED PATH NOS TO BE USED FOR LAYER EMISSION IN ORDER OF THE DIRECTION OF RADIATION TRAVEL
                               -----------------------------------------------------------------------------------------------------
                           1     40  39  38  37  36  35  34  33  32  31  30  29  28  27  26  25  24  23  22  21  21  22  23  24  25
                                 26  27  28  29  30  31  32  33  34  35  36  37  38  39  40

          3      40        2     20  19  18  17  16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1   1   2   3   4   5
                                  6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
 VIEWING  PARAMETER =  1
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

 SPECTRA WILL BE INTEGRATED OVER THE WIDEMESH INTERVALS.
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

 *************** CALCULATION BEGINS ***************

&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&


 *************** ELAPSED CPU TIME:    0:54:44.87 ***************
```

Ex.2. Limb View: Program GENLN2

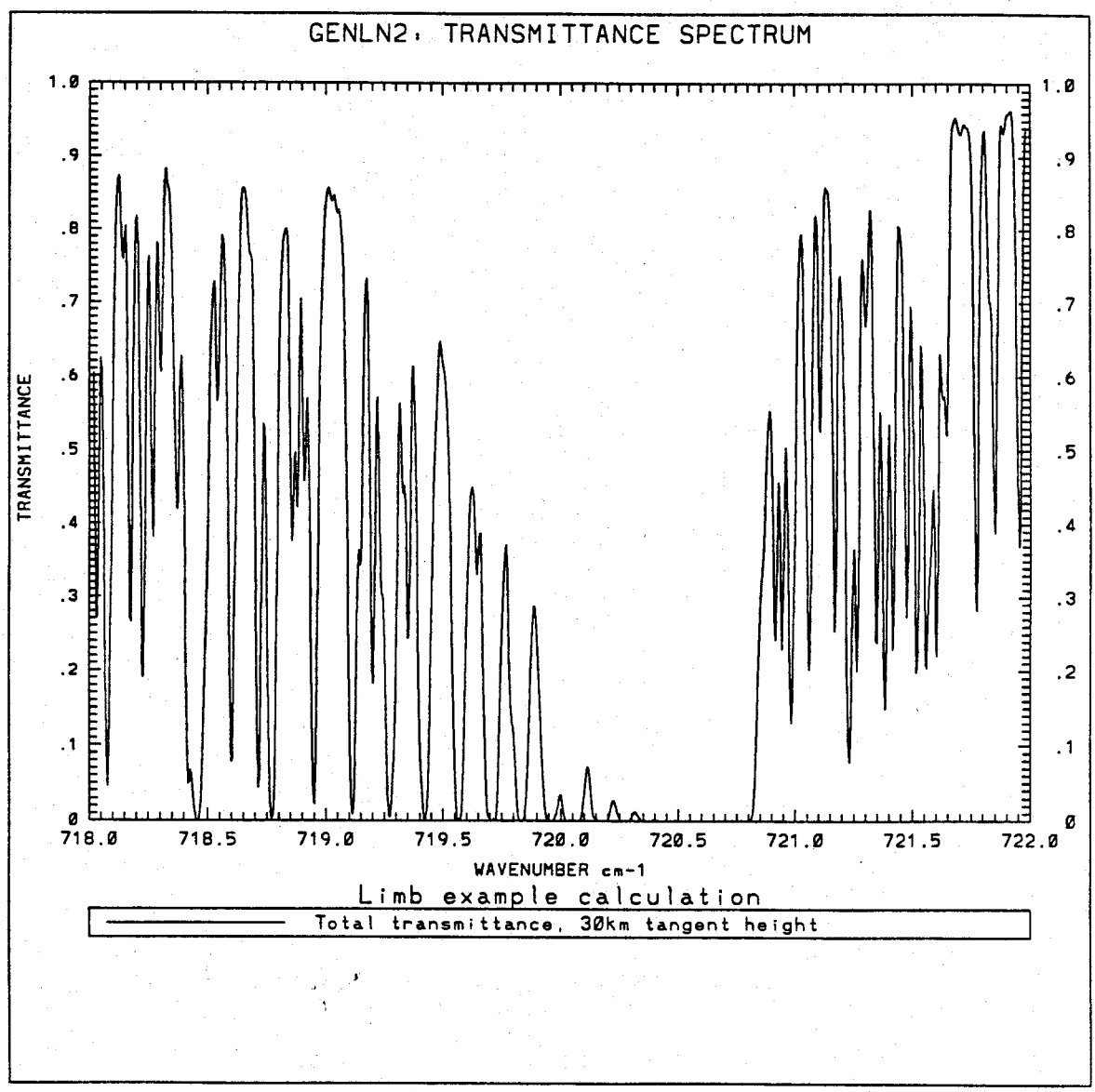
ex2_genln2_opd.dat

```
*************** CALCULATION COMPLETE. ***************
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

INTEGRATED ATMOSPHERIC LAYER TRANSMITTANCES AND BOUNDARY RADIANCES
******************************************************************

*** ATMOSPHERE   1 ***

*** LAYER NO.   40 ***
INTERVAL  LOW BDY cm-1  UPP BDY cm-1  FINE MESHES    TRANSMITTANCE     BDY RADIANCE
                                                                    W/(m2.sr.cm-1)
-----------------------------------------------------------------------------------
       1       718.000       719.000         4000      .496800E+00      .209419E-01
       2       719.000       720.000         4000      .286851E+00      .356913E-01
       3       720.000       721.000         4000      .618608E-01      .546551E-01
       4       721.000       722.000         4000      .611289E+00      .131767E-01
AVERAGE VALUES OVER PASSBAND                           .364200E+00      .311162E-01

*** ATMOSPHERE   2 ***

*** LAYER NO.   40 ***
INTERVAL  LOW BDY cm-1  UPP BDY cm-1  FINE MESHES    TRANSMITTANCE     BDY RADIANCE
                                                                    W/(m2.sr.cm-1)
-----------------------------------------------------------------------------------
       1       718.000       719.000         4000      .496800E+00      .749775E-02
       2       719.000       720.000         4000      .286851E+00      .500115E-02
       3       720.000       721.000         4000      .618608E-01      .483975E-02
       4       721.000       722.000         4000      .611289E+00      .840466E-02
AVERAGE VALUES OVER PASSBAND                           .364200E+00      .643582E-02

*** ATMOSPHERE   3 ***

*** LAYER NO.   40 ***
INTERVAL  LOW BDY cm-1  UPP BDY cm-1  FINE MESHES    TRANSMITTANCE     BDY RADIANCE
                                                                    W/(m2.sr.cm-1)
-----------------------------------------------------------------------------------
       1       718.000       719.000         4000      .496800E+00      .284394E-01
       2       719.000       720.000         4000      .286851E+00      .406923E-01
       3       720.000       721.000         4000      .618608E-01      .594947E-01
       4       721.000       722.000         4000      .611289E+00      .215815E-01
AVERAGE VALUES OVER PASSBAND                           .364200E+00      .375520E-01


*************** END OF DATA OUTPUT ***************


*************** GRAPHICS FILE WRITTEN TO: ex2_genln2_ops.dat                                ***************
```

Ex.2. Limb View: Program GENGRP

ex2_gengrp_trans.dat

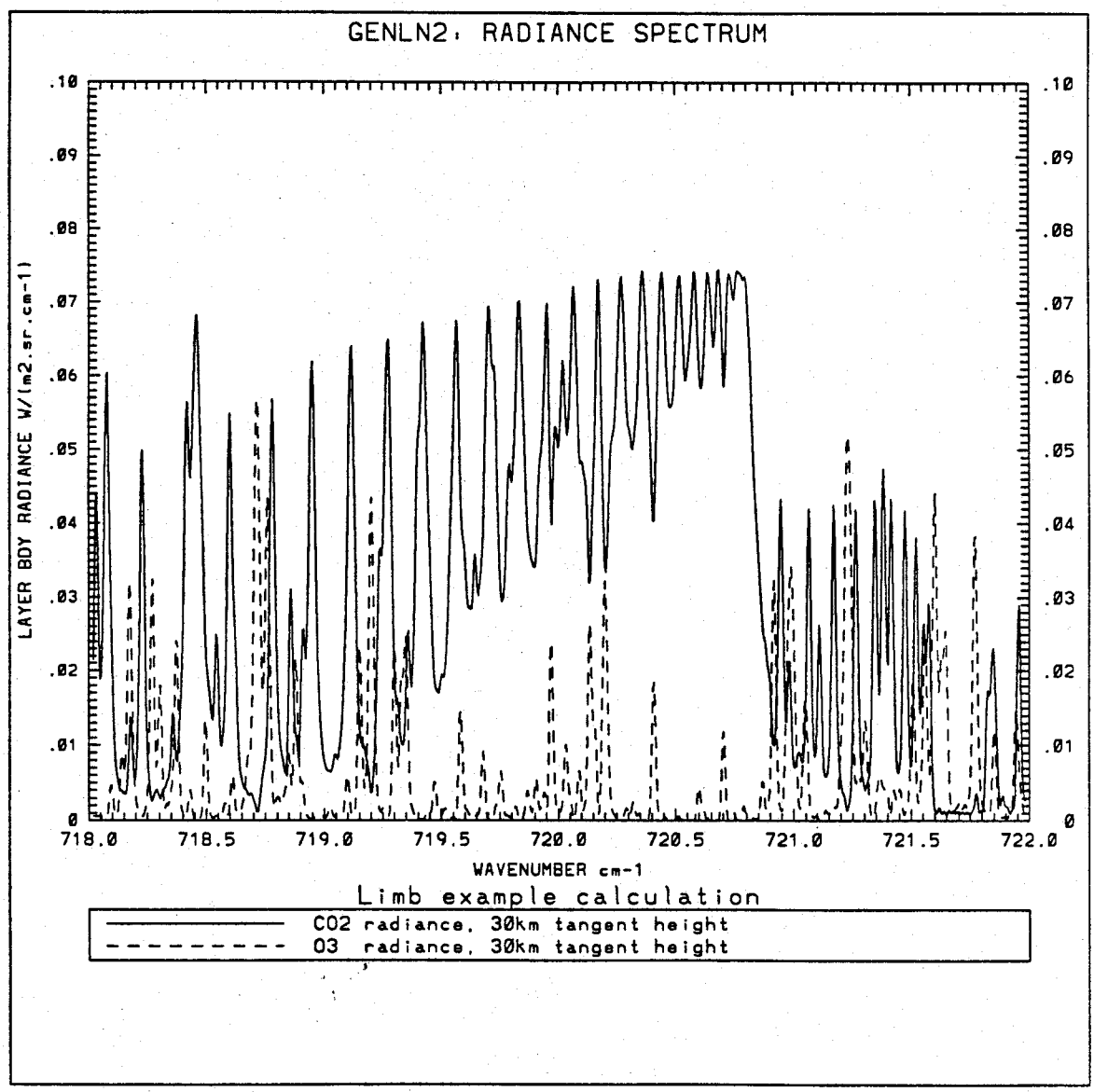

```
##################################################
##################################################
##                PROGRAM GENGRP                ##
##                --------------                ##
##  GENERAL PURPOSE GRAPHICS FOR PLOTTING       ##
##  GENLN2 TRANSMITTANCE AND RADIANCE SPECTRA   ##
##  VERSION 3.0   D.P. EDWARDS   27/02/91       ##
##  (C) COPYRIGHT 1991 UCAR/NCAR                ##
##  ALL RIGHTS RESERVED                         ##
##  GENLN2 SOFTWARE AND RELATED MATERIALS MAY   ##
##  BE USED ONLY UNDER AN EXECUTED VALID        ##
##  LICENCE AGREEMENT                           ##
##################################################
##################################################


**Q** Name of GENLN2 unformatted output file to plot? :
ex2_genln2_ops.dat
**Q** Enter filename of output graphics metacode file :
ex2_gengrp_trans.meta
**Q** Do you want the default picture size [Y/N] :
Y
**Q** For a default axis, the axis drawn will be
      that appropriate for the first curve entered.
      Is a default X-axis to be drawn? [Y/N] :
Y
**Q** Is a default Y-axis to be drawn? [Y/N] :
Y
**Q** Enter the no. of curves to be plotted on this graph? :
1
**Q** Do you want to supply your own curve captions? [Y/N] :
Y
##### CURVE NO.  1 #####
**Q** Is a path transmittance spectrum                    (PT),
      a mixed path transmittance spectrum                 (XT),
      a radiating atmosphere layer transmittance spectrum (AT),
      or a radiating atmosphere layer radiance spectrum   (AR)
      to be plotted?
      Enter one of PT, XT, AT or AR :
AT
**Q** Curve   1. IATM no. of layer atmosphere? :
3
**Q** Curve   1. ILAY no. of layer to be plotted? :
40
**Q** Are wide mesh binned spectral values to be plotted? [Y/N] :
N
**Q** Enter line type and pen type for drawing curve LTYPE,IPEN :
1,2
**Q** Enter curve caption, 50 chars. max. :
Total transmittance, 30km tangent height
**Q** Do you want to degrade the spectra with an
      instrument line shape (ILS) function? [Y/N] :
Y
**Q** ILS function type specifier;
      1 = square boxcar
      2 = triangle
      3 = Fourier spec. (only with evenly spaced points)
      4 = user supplied (only with evenly spaced points)
      Enter 1,2,3 or 4 :
3
**Q** Enter max. retardation length in cm :
50.0
**Q** Fourier apodization specifier;
      1 = no apodization
      2 = triangular apodization
      3 = Norton & Beer weak apodization
      4 = Norton & Beer medium apodization
      5 = Norton & Beer strong apodization
      Enter 1,2,3,4 or 5 :
4
**Q** Are all points to be plotted? [Y/N] :
N
**Q** Enter no of plot points/cm-1 :
200
**Q** Is an external spectra to be plotted? [Y/N] :
N
```


GENLN2: TRANSMITTANCE SPECTRUM
TRANSMITTANCE
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0
718.0
718.5
719.0
719.5
720.0
720.5
721.0
721.5
722.0
WAVENUMBER cm-1
Limb example calculation
Total transmittance, 30km tangent height

Ex.2. Limb View: Program GENGRP

ex2_gengrp_rad.dat


```
##############################################
##############################################
##                PROGRAM GENGRP            ##
##                --------------            ##
##  GENERAL PURPOSE GRAPHICS FOR PLOTTING   ##
##  GENLN2 TRANSMITTANCE AND RADIANCE SPECTRA ##
##  VERSION 3.0   D.P. EDWARDS   27/02/91   ##
##  (C) COPYRIGHT 1991 UCAR/NCAR            ##
##  ALL RIGHTS RESERVED                     ##
##  GENLN2 SOFTWARE AND RELATED MATERIALS MAY ##
##  BE USED ONLY UNDER AN EXECUTED VALID    ##
##  LICENCE AGREEMENT                       ##
##############################################
##############################################


**Q** Name of GENLN2 unformatted output file to plot? :
ex2_genln2_ops.dat
**Q** Enter filename of output graphics metacode file :
ex2_gengrp_rad.meta
**Q** Do you want the default picture size [Y/N] :
Y
**Q** For a default axis, the axis drawn will be
      that appropriate for the first curve entered.
      Is a default X-axis to be drawn? [Y/N] :
Y
**Q** Is a default Y-axis to be drawn? [Y/N] :
Y
**Q** Enter the no. of curves to be plotted on this graph? :
2
**Q** Do you want to supply your own curve captions? [Y/N] :
Y
##### CURVE NO.  1 #####
**Q** Is a path transmittance spectrum                    (PT),
      a mixed path transmittance spectrum                 (XT),
      a radiating atmosphere layer transmittance spectrum (AT),
      or a radiating atmosphere layer radiance spectrum   (AR)
      to be plotted?
      Enter one of PT, XT, AT or AR :
AR
**Q** Curve   1. IATM no. of layer atmosphere? :
1
**Q** Curve   1. ILAY no. of layer to be plotted? :
40
**Q** Are wide mesh binned spectral values to be plotted? [Y/N] :
N
**Q** Enter line type and pen type for drawing curve LTYPE,IPEN :
1,2
**Q** Enter curve caption, 50 chars. max. :
CO2 radiance, 30km tangent height
##### CURVE NO.  2 #####
**Q** Is a path transmittance spectrum                    (PT),
      a mixed path transmittance spectrum                 (XT),
      a radiating atmosphere layer transmittance spectrum (AT),
      or a radiating atmosphere layer radiance spectrum   (AR)
      to be plotted?
      Enter one of PT, XT, AT or AR :
AR
**Q** Curve   2. IATM no. of layer atmosphere? :
2
**Q** Curve   2. ILAY no. of layer to be plotted? :
40
**Q** Are wide mesh binned spectral values to be plotted? [Y/N] :
N
**Q** Enter line type and pen type for drawing curve LTYPE,IPEN :
2,3
**Q** Enter curve caption, 50 chars. max. :
O3  radiance, 30km tangent height
**Q** Do you want to degrade the spectra with an
      instrument line shape (ILS) function? [Y/N] :
Y
**Q** ILS function type specifier;
      1 = square boxcar
      2 = triangle
      3 = Fourier spec. (only with evenly spaced points)
      4 = user supplied (only with evenly spaced points)
      Enter 1,2,3 or 4 :
3
**Q** Enter max. retardation length in cm :
50.0
**Q** Fourier apodization specifier;
      1 = no apodization
      2 = triangular apodization
      3 = Norton & Beer weak apodization
      4 = Norton & Beer medium apodization
      5 = Norton & Beer strong apodization
      Enter 1,2,3,4 or 5 :
4
**Q** Are all points to be plotted? [Y/N] :
N
**Q** Enter no of plot points/cm-1 :
200
**Q** Is an external spectra to be plotted? [Y/N] :
N
```


GENLN2: RADIANCE SPECTRUM
LAYER BDY RADIANCE W/(m2.sr.cm-1)
.10
.09
.08
.07
.06
.05
.04
.03
.02
.01
0
718.0
718.5
719.0
719.5
720.0
720.5
721.0
721.5
722.0
WAVENUMBER cm-1
Limb example calculation
CO2 radiance, 30km tangent height
O3 radiance, 30km tangent height

APPENDIX 3. EXAMPLE PMR CALCULATION

A3.1 Overview of Example PMR Calculation

This appendix describes how GENLN2 can be used to model a pressure modulator radiometer (PMR). A PMR is a gas correlation radiometer in which the atmospheric radiation passes through a cell containing the same gas as the atmospheric gas which is being measured. The gas pressure inside the cell is modulated, resulting in a modulation in the opacity of the cell due to that component of the atmospheric radiation that was emitted by the cell gas species. This produces fluctuations in the signal at the detector only inside the spectral lines of the gas species contained in the cell. High effective resolution and signal-to-noise ratio are possible because contributions from all lines of the cell gas species are sampled. The principles and operation of PMRs are discussed in detail by *Taylor* (1983). The pressure cycle used in the cell determines the part of the spectral line that is sampled. A wideband radiometer mode is also possible and is achieved by asynchronously chopping the input signal with the pressure modulation to measure the mean radiation transmitted by the cell.

The following discussion briefly sets out the method. This is followed by a simple worked example that demonstrates the running of the various programs.

A3.2 Modelling the PMR Response Functions

Let $I(\nu, z_{obs})$ be the radiation in $W/(m^2.sr.cm^{-1})$ falling on a radiometer. For a radiometrically self-calibrating instrument the signal R is the ratio between the atmospheric and blackbody emission

$$R = \frac{\int_0^\infty I(\nu, z_{obs}) F(\nu) d\nu}{\int_0^\infty B(\nu, T_B) F(\nu) d\nu} \qquad (A3.1)$$

where $F(\nu)$ is the total radiometer response function and $B(\nu, T_B)$ is the blackbody radiance at the reference temperature T_B.

The total radiometer response can be written as the product of the response profile of the wide band channel blocker, $G(\nu)$, and the gas correlation response, $H(\nu)$,

$$F(\nu) = G(\nu)\ H(\nu). \qquad (A3.2)$$

Assume now that the radiometer channel blocker response profile $G(\nu)$ varies very slowly over the wavenumber width of a GENLN2 wide mesh interval width $\delta\nu$. If there are N wide mesh intervals i, which need not have equal spacing, then Eqn.A3.1 can be written

$$R = \frac{\sum_{i=1}^{N} \overline{G}_i \int_{\delta\nu_i} I(\nu, z_{obs}) H(\nu) d\nu}{\sum_{i=1}^{N} \overline{G}_i \int_{\delta\nu_i} B(\nu, T_B) H(\nu) d\nu} \qquad (A3.3)$$

where

$$\overline{G}_i = \frac{1}{\delta\nu_i} \int_{\delta\nu_i} G(\nu) d\nu. \qquad (A3.4)$$

The ISAMS instrument aboard the Upper Atmosphere Research Satellite (UARS) mission (*Reber*, 1985) uses several PMRs for sounding various atmospheric gases. The two functions $G(\nu)$ and $H(\nu)$ for the CO_2 channel 7.1 PMR, defined in Section A3.4, are shown in Fig.A3.1.

A3.3 The Gas Correlation Response Function

A schematic diagram of a PMR is shown in Fig.A3.2. At the center of a purely collision broadened spectral line the PMR absorption for a given cell length and temperature is independent of cell pressure and the radiometer response is zero. Away from the line center the response rises to a maximum and then decreases, the exact form depending on the optical thickness. For the optically thin case, the maximum occurs at line center$\pm\sqrt{\overline{\alpha_L}}$ where $\overline{\alpha_L}$ is Lorentz half width evaluated at the cell mean pressure, see Fig.A3.3. The insert on Fig.A3.1 shows an enlargement of the PMR response function for the ISAMS CO_2 channel 7.1 example PMR and shows the double maximum and central depression. If Doppler broadening is also present then the absorption at line center is greater during the high-pressure part of the modulator cycle and the response is greater than zero. If the temperature or cell length also vary then the response can be positive or negative.

The PMR cycle can be represented as a linear combination of M gas cells each containing the PMR gas. Each cell has the same length but the pressure and possibly the temperature differ according to the point that the cell represents on the modulation curve. The gas correlation response is then approximated as a weighted linear combination of the monochromatic transmittances of each cell

$$H(\nu) = \sum_{j=1}^{M} a_j \; \tau_j(\nu)^{cell} \qquad (A3.5)$$

where $\tau_j(\nu)^{cell}$ is the transmittance of cell j and a_j is the weighting coefficient. In this way the commonly used two-cell approximation is modelled by setting $M = 2$, cell 1 is the high pressure cell with $a_1 = -1$ and cell 2 is the low pressure cell with $a_2 = +1$. The gas correlation response in this case is

$$H(\nu) = \tau_2(\nu)^{low\ p\ cell} - \tau_1(\nu)^{high\ p\ cell}. \qquad (A3.6)$$

The two-cell wideband calculation is modelled by setting both a_1 and a_2 to 0.5 with the same cell transmittances. For a sinusoidal pressure cycle, cells can be defined at various times along the cycle with the corresponding pressure, temperature, and gas amount. The weight of each cell is then equal to the sine of the time at which the cell is defined. For a symmetric modulator cycle, the sum of the coefficients in the PMR case should be zero and in the wideband case it should be unity.

The gas correlation response function $H(\nu)$ depends on the PMR cell pressure and temperature cycles. Thus the same function will be applicable to many atmospheric radiance calculations that use the same PMR. The approach taken in GENLN2 is to pre-compute $H(\nu)$ for a particular PMR on the fine wavenumber grid and to store the result in a file for subsequent GENLN2 atmospheric calculations to use. This avoids duplication of cell transmittance calculations and makes possible a PMR representation with a larger number of composite cells.

Away from strong absorption lines of the PMR cell gas, the response function $H(\nu)$ approaches zero. At such points it is unnecessary to compute the line-by-line radiance. The GENLN2 wide mesh wavenumber boundaries are chosen such that they fall either side of regions of non-zero response. Wide meshes with zero response are then flagged. Because the response function and the wide mesh boundaries are input at the start of the GENLN2 calculation, line-by-line calculation in these meshes can be switched off to save time.

A3.4 Example PMR Calculation: ISAMS CO_2 Channel 7.1

There follows a description of the stages for modelling a PMR using GENLN2. The example is that of the ISAMS instrument CO_2 channel 7.1. A simple 2-cell PMR calculation is used for a 30 *km* tangent height limb view of the atmosphere.

The spectral region of interest is 590–640 cm^{-1} with the channel center at 615 cm^{-1}.
Assume a CO_2 PMR with a 40 *mb* mean pressure and compression ratio of 2.5 .
The cell length is 30 *mm*.
The reference blackbody temperature T_B is 296 K.
The Cell temperature, which is assumed constant, is 290 K.

Using the 2-cell approximation:

Cell 1: Low pressure $= 2.5^{-0.5} \times 40\ mb = 25.2982\ mb = 0.02496\ atm$
Gas amount $= 3.06315 \times 10^{-9}\ kg.moles.cm^{-2}$

Cell 2: High pressure $= 2.5^{+0.5} \times 40\ mb = 63.2455\ mb = 0.06242\ atm$
Gas amount $= 7.65788 \times 10^{-9}\ kg.moles.cm^{-2}$

A3.5 Program GENLN2: Calculation of the cell transmittances

In the discussion that follows it is assumed that the reader is familiar with the usual stages of a GENLN2 calculation as described in example calculations 1 and 2. The emphasis here will be on those stages specific to the PMR calculation. The previously calculated line data file **ex2_hitlin_op.dat** is used, Section A2.2.

The first task is to calculate the gas correlation response function $H(\nu)$. This is achieved with a run of GENLN2 where the gas paths that are defined in the *PTHPAR section of the input file represent the cells of the modulation cycle, see **ex3_genln2_ipr.dat**. It is important that the gas amount for each cell is consistent with the cell pressure and it is wise to give these quantities to several significant figures. The wavenumber range and resolution of this calculation must correspond to those required for the eventual atmospheric calculations. The path transmittances calculated on the fine wavenumber grid, IDAT=1 in *OUTPUT are written to the unformatted output file **ex3_genln2_opsr**. A listing is given of the formatted output summary file **ex3_genln2_opdr.dat**.

A3.6 Program PMRFIL

The interactive program PMRFIL is used at this stage. This consists of two subroutines:

PMRFIL - Main program. Manages input and output, calculates the gas correlation response function filter on the fine wavenumber grid. Unit 6 is used to write interactive questions and unit 5 to read the answers. Unit 10 is used to read the GENLN2 unformatted output file.

PMREXT - Subroutine. Calculates the wide mesh wavenumber interval boundaries to correspond with region of non-zero filter response. Intervals of zero response are flagged. Unit 30 is used to write the output filter response data file.

Input to this program consists of the GENLN2 output file **ex3_genln2_opsr.dat** and the user will be prompted for the path number to be associated with each cell and the cell weighting coefficients described in Section A3.3. The input dialogue for this calculation is shown in **ex3_pmrfil_ip.dat**.

The program first performs the linear combination of weighted cell transmittances. The optimal wide mesh wavenumber boundaries are then calculated. The user is prompted for

the minimum absolute value of $H(\nu)$ to be treated as non-zero, the maximum number of fine grid points per wide mesh interval, the maximum number of wide meshes, and the wide mesh spacing. The values chosen for these quantities should be consistent with the maximum array sizes chosen for the subsequent GENLN2 calculations. The code identifies regions of predominantly non-zero response and these are enclosed by wide mesh wavenumber boundaries. The boundaries are then adjusted iteratively to satisfy the input criteria. Zero response wide meshes are flagged so that the subsequent GENLN2 line-by-line calculation is switched off.

This and the previous calculation stages need only be performed once for a particular PMR. The output response file **ex3_pmrfil_op.dat** is stored and used for all subsequent GENLN2 atmospheric radiance calculations that use this PMR.

A3.7 Program GENLN2: Atmospheric Calculation

The calculation is performed for 30 km tangent height limb view of the U.S. 1976 Standard atmosphere. Two gases, CO_2 and O_3, are included in each layer. The atmosphere is assumed to be the same as that of example calculation 2 and the same set of path data from **ex2_layers_op.dat** are used by GENLN2, See Section A2.3. Line data is taken from the previously calculated line data file **ex2_hitlin_op.dat**, Section A2.2. Line coupling is included in the calculation as described in Section A2.4.

The wavenumber grid for a PMR calculation is defined using *RADIOM input option. This keyword input section is described below. See also Table 4.1 and the input wavenumber parameters illustrated in Fig.4.1.

***RADIOM**
This section is used to input the wavenumber parameters for a GENLN2 calculation using a radiometer spectral filter. It must not be used in conjunction with the equivalent input sections *USEGRD, *GRDFIL, *DEFGRD, or *SPECTM. (1A) **FEXC** (real) is the wavenumber range in cm^{-1} either side of a wide mesh interval for which the fine-pass calculation is performed. For wide mesh interval IPW a line-by-line absorption calculation is performed over the fine wavenumber grid FF(IPT,IPW) for line center wavenumbers WNUM cm^{-1} falling in the range
FBDY(IPW+NPL−1) − FEXC ≤ WNUM ≤ FBDY(IPW+NPL) + FEXC
(1B) **FWIND** (real) is the wavenumber range cm^{-1} either side of a wide mesh interval outside of which lines are not considered. The line wing absorption calculation is performed over the three wavenumber points FW(IP,IPW) of the wide mesh for line center wavenumbers WNUM cm^{-1} falling in the ranges
FW(IP,IPW) − FWIND ≤ WNUM < FBDY(IPW+NPL−1) − FEXC and
FW(IP,IPW) +FWIND ≥ WNUM > FBDY(IPW+NPL) + FEXC.
FWIND should be set equal to 25 cm^{-1} if a continuum absorption calculation is to be performed as discussed in Section 4.6.
(1C) **DELWNG** (real) is the constant wide mesh interval spacing in cm^{-1} that is used in the wing regions either side of the passband. This should have a value of about 1 cm^{-1}. (2A) **RESFI** (80 character string) is the file name of the radiometer response profile. This is the output file of the PMRFIL program, **ex3_pmrfil_op.dat.**

The *PTHFIL and *MIXING input sections are the same as were used for example calculation 2, Section A2.4.

Two radiance calculations are performed. The first is for the atmospheric limb path, the second for an internal PMR view of the instrument blackbody. This is required for self-calibration as shown in Eqn.A3.1.

For the atmospheric radiance calculation, the layer emission parameter IEMS=1 and an emis-

sion calculation is not performed. In this case the same set of mixed path optical depths (20 down to 1 at the tangent point, and then 1 to 20 back to space) are used to define the atmosphere in both absorption and emission, therefore giving the total radiance. A 40 layer atmosphere is defined with the radiometer situated at the furthest boundary of layer 40.

For the blackbody calculation, IVIEW=2 since there is blackbody at the initiating surface of the radiance calculation. Since there are no atmospheric layers between the blackbody and the PMR NLAY=0, and IEMS and LAYSP become dummy inputs. Since there are no atmospheric layers, there are no layer indices to be specified. The emittance EMSTY of the blackbody at TINIT=290 K is set equal to 1.0 so making TBDY a dummy input.

The *INTEGN section is included so the radiance spectra will be convolved with the PMR response function. After the GENLN2 line-by-line calculation the quantity output as the integrated average radiance over wide mesh i is now

$$\overline{I_i} = \frac{\int_{\delta\nu_i} I(\nu, z_{obs}) H(\nu) d\nu}{\overline{H_i}} \qquad (A3.7)$$

where

$$\overline{H_i} = \int_{\delta\nu_i} H(\nu) d\nu. \qquad (A3.8)$$

Selection of the spectra to be output is made in in the *OUTPUT section. The integrated radiance spectra IDAT=9 at layer 40 for the radiating atmosphere calculation and at layer 0 for the blackbody calculation are selected. Note that if fine grid transmittances or radiances were output at this stage, they would **not** be weighted by the response function.

A listing is given of the formatted summary output data file. This gives a summary of the GENLN2 input to the calculation together with the integrated spectra specified for output in *TITLES. The input file, **ex3_genln2_ip.dat**, and the formatted summary output data file, **ex3_genln2_opd.dat**, should be assigned to FORTRAN units 4 and 30 respectively before execution.

A3.8 Program BRIGHT

In program BRIGHT the radiances weighted by the PMR response $H(\nu)$ and averaged over each wide mesh interval are convolved with the ISAMS channel 7.1 blocker response profile $G(\nu)$. This is supplied in the ESDA format, Section 5.3, and listed in **ex3_bright_res.dat**. The input dialogue is shown in **ex3_bright_ip.dat**.

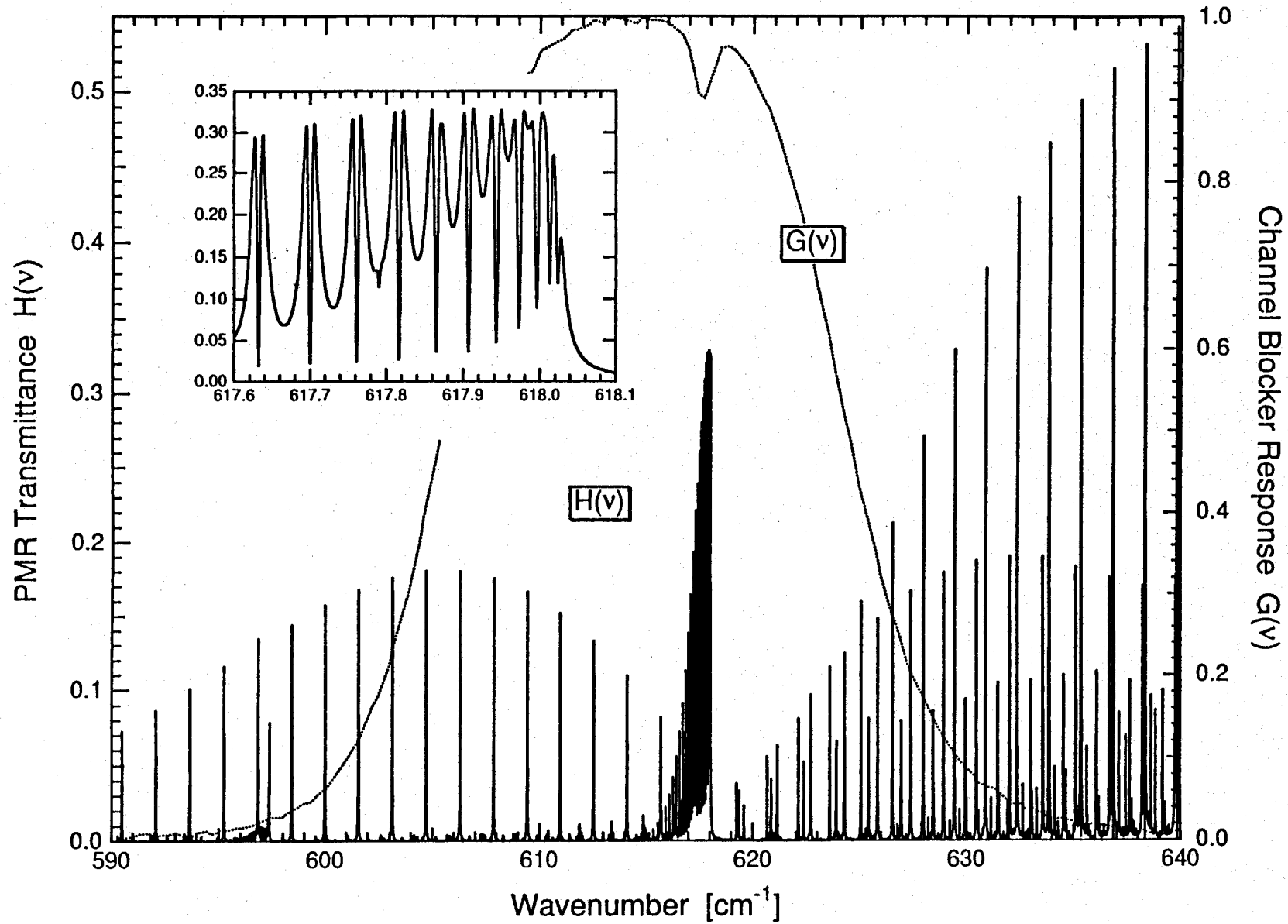
The calculation performed by BRIGHT can be written,

$$S = \frac{\sum_i \overline{G_i} \overline{I_i} \ \overline{H_i}}{\sum_i \overline{G_i} \overline{H_i}}. \qquad (A3.9)$$

If S_{atm} is the convolved atmospheric radiance at this stage and S_{BB} is the convolved blackbody emission then the self-calibrating signal R, see Eqn.A3.1, becomes

$$R = S_{atm}/S_{BB}. \qquad (A3.10)$$

ISAMS Ch. 7.1 Response Functions



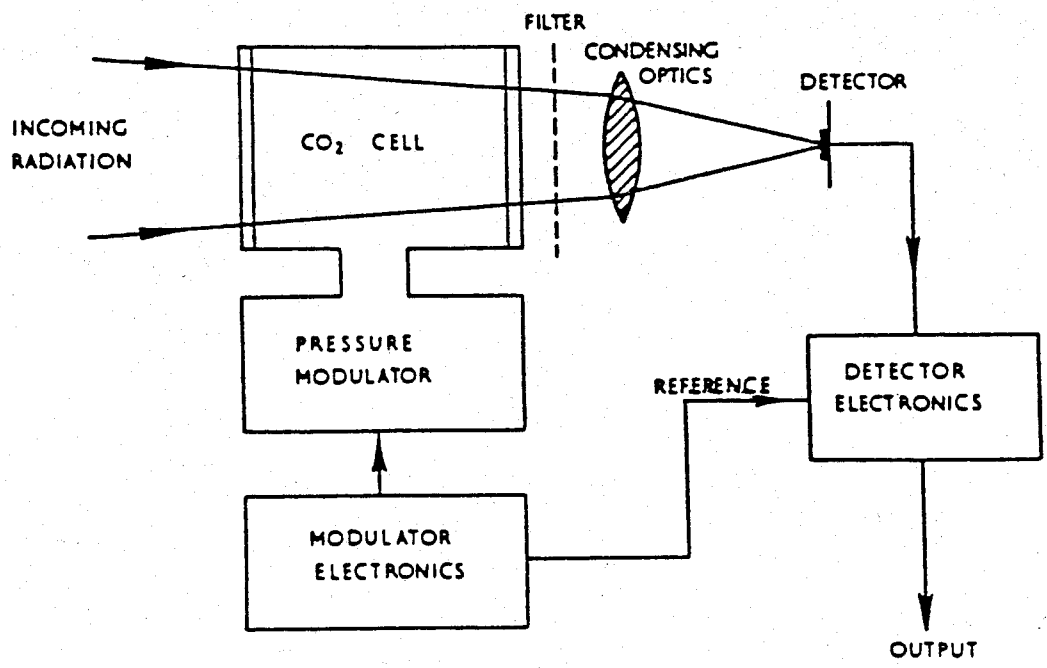


Fig A3.2. Principle features of a pressure modulator radiometer (PMR). *From Taylor (1983).*

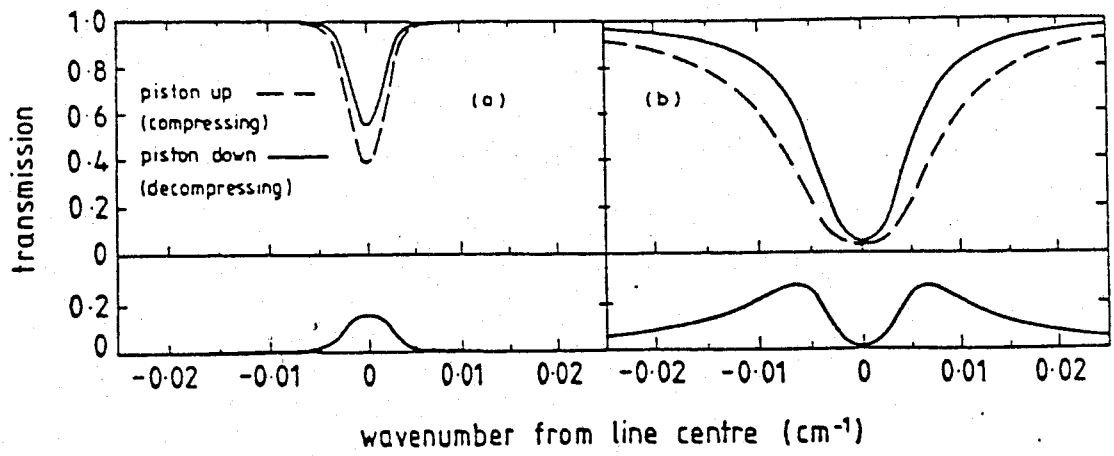


Fig A3.3. The transmittance of a line in a PMR cell (upper curves) and the resultant response function (lower curves), being the difference between the two upper curves, for the case of an unsaturated Doppler-broadened line (a), and for a saturated pressure-broadened line (b). *From Roscoe and Wells (1989).*

```
!
!
!                 ******************************************
!                 *                                        *
!                 *        PROGRAM GENLN2: INPUT FILE      *
!                 *        --------------------------      *
!                 *  INPUT FILE FOR THE GENLN2 LINE-BY-LINE *
!                 *  COMPUTER MODEL. CALCULATES ATMOSPHERIC *
!                 *  TRANSMITTANCE AND RADIANCE.            *
!                 *  VERSION 3.0: D.P. EDWARDS 21/08/90     *
!                 *                                        *
!                 ******************************************
!                                                   INPUT PARAMETER NAME
!-----------------------------------------------------------------------------
!..TITLE INFOMATION AND SUMMARY OUTPUT SPECIFICATION FOR THIS GENLN2 RUN
!..(*TITLES) [MANDATORY]
*TITLES
!
!      1A. Title of this GENLN2 run (40 characters MAX) :                TITLE
'ISAMS CO2 Ch7.1 Response'
!
!      2A. Passband average spectral values only are printed in
!          formatted summary output file if logical is set true:         AVER
!      2B. Mixing table not printed if logical is set true:              MXER
.FALSE., .TRUE.
!
!      Data to be printed in the formatted summary output file is
!      specified by the IDAT parameter for the following categories:-
!      IDAT = 1  Path integrated transmittance spectrum.
!           = 2  Mixed path integrated transmittance spectrum.
!           = 3  Radiating atmosphere layer integrated
!                transmittance and radiance spectra.
!      The following section is repeated for each required IDAT.
!----------
!      3A. Index (1,2 or 3 above):                                       IDAT
1
!
!      If  IDAT = 1 or IDAT = 2:
!      4A. No. of paths or mixed paths to be printed: NP;
!          if all paths are to be print set NP<0.
-1
!      Else if IDAT=3:
!      4A. Atmosphere no. for printing:                                  IATM
!          if all atmospheres are to be printed set IATM<0.
!      4B. no. of layers to be printed:                                  NP
!          if all layers are to be printed set NP<0.
!
!      For all IDAT:
!      5A. List of path, mixed path or layer nos. for printing;
!          only required if NP>0:                  (IOPDT(IDAT,IATM,I),I=1,NP)
!----------
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..THE GAS LINE DATA FILE(S) TO BE USED (*GASFIL) [MANDATORY]
*GASFIL
!
!      1A. No. of line data files to be read:                            NFILE
!      1B. Machine specifier, determines record length:                  MACH
!          MACH=1: 4 byte/word, OPEN RECL in words (eg. VAX, ANSII stand)
!          MACH=2: 4 byte/word, OPEN RECL in bytes (eg. IBM RISC)
!          MACH=3: 8 byte/word, OPEN RECL in bytes (eg. CRAY)
!          This should be the same as was used in HITLIN
1, 2
!
!      For each file (IFILE=1,NFILE) 4 input records
!----------
!      2A. Filename of line data file:                                   FNAM(IFILE)
'ex2_hitlin_op.dat'
!
!      3A. No. of gases to be read from this file:                       NGAS(IFILE)
1
!
!      4A. Molecular ID's of the gas(es) to be read:
!                                        (LGASES(IFILE,IGAS),IGAS=1,NGAS(IFILE))
2
!
!      5A. Line data version(s) to be chosen:
!                                        (LCHOSE(IFILE,IGAS),IGAS=1,NGAS(IFILE))
11
!----------
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..LINE COUPLING CALCULATION FOR FLAGGED LINES ON THE DATABASE (*LINMIX)
!..[NOT MANDATORY]
*LINMIX
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..DEFAULT CALCULATION OF WIDE MESH BOUNDARY WAVENUMBER GRID (*DEFGRD)
!..[MANDATORY if one of *USEGRD, *GRDFIL or *RADIOM is not supplied]
*DEFGRD
!
!      1A. The minimum wavenumber to be considered (cm-1):               FMIN
!      1B. the lower integration (passband) wavenumber (cm-1):           FPSL
!      1C. the upper integration (passband) wavenumber (cm-1):           FPSU
!      1D. the maximum wavenumber to be considered (cm-1):               FMAX
!      1E. the wide mesh constant wavenumber interval spacing (cm-1):    DELTA
565.0   590.0   640.0   665.0   1.0
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..PARAMETERS DEFINING THE SPECTRAL CALCULATION REGIONS (*SPECTM)
!..[MANDATORY with *USEGRD, *GRDFIL or *DEFGRD.
!..Must not appear if *RADIOM is supplied]
*SPECTM
!      1A. The wavenumber range either side of a wide mesh interval for
!          which a fine grid line-by-line calculation is performed (cm-1): FEXC
!      1B. the wavenumber range either side of the current interval
!          outside of which lines are not considered (cm-1):             FWIND
!      1C. the parameter specifying the division of the wide mesh
!          wavenumber interval to produce the fine mesh wavenumber grid: NDIV
1.0, 25.0, 2000
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..PATH PARAMETERS (*PTHPAR)
*PTHPAR
!
!      1A. No. of paths to be read from this file:                       NPATH
2
!
!      For each path (IPATH=1,NPATH) 2 input records
!----------
!      Path parameters required are:-
!      2A. The file (IFILE) off of which the path gas is to be read:IDFIL(IPATH)
!      2B. the molecular ID of the path gas:                        IDGAS(IPATH)
!      2C. the isotope abundance ID of the path gas:                IDISO(IPATH)
!      2D. the amount of gas in the path (kg.moles/cm2):              AMT(IPATH)
!      2E. the average path temperature (K):                            T(IPATH)
!      2F. the total gas pressure of the path (atm):                    P(IPATH)
!      2G. the partial pressure of the path gas (atm):              PARTP(IPATH)
```

```
!      2H. the gas velocity (m/s) not used at present:                VEL(IPATH)
!
!      3A. Lineshape to be used for this path:                      LINSHP(IPATH)
!      3B. Continuum specifier for this path 'CON' or 'NOCON':        CONT(IPATH)
!      Character variables must be enclosed by quotes.
!----------
! Cell 1. Ch.7.1    29.2982 mb  Low pressure cell
1, 2, 0, 3.06315E-9, 290.0, 0.02496, 0.02496, 0.0
'VOIGTCO2',  'CON'
!
! Cell 2. Ch.7.1    63.2455 mb  High pressure cell
1, 2, 0, 7.65788E-9  290.0, 0.06242, 0.06242, 0.0
'VOIGTCO2',  'CON'
!
!----------
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..INTEGRATION SWITCH (*INTEGN) [NOT MANDATORY]
*INTEGN
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..UNFORMATTED OUTPUT FILE SPECIFICATION (*OUTPUT) [NOT MANDATORY]
*OUTPUT
!
!      1A. File name of output file:                                    OPFNAM
'ex3_genln2_opsr.dat'
!
!      Data to be output is specified by IDAT parameter
!      for the following categories:-
!      IDAT= 1  Path point transmission spectrum;
!          = 2  Path integrated transmission spectrum;
!          = 3  Mixed path point transmission spectrum;
!          = 4  Mixed path integrated transmission spectrum;
!          = 5  Layer point transmission spectrum;
!          = 6  Layer integrated transmission spectrum;
!          = 7  Layer point radiance spectrum;
!          = 8  Layer integrated radiance spectrum.
!      The following section is repeated for each required IDAT.
!----------
!      2A. Index (1 thro' 10 above):                                      IDAT
1
-1
!
!      For IDAT = 1, 2, 3 or 4:
!      3A. no. of paths or mixed paths to be printed:                       NP
!          if all paths are to be print set NP<0.
!      For IDAT = 5, 6, 7 or 8:
!      3A. atmosphere no. for printing:                                   IATM
!          if all atmospheres are to be printed set IATM<0.
!      3B. no. of layers to be printed:                                     NP
!          if all layers are to be printed set NP<0.
!
!      For all IDAT:
!      4A. List of path, mixed path or layer nos. for printing;
!          only required if NP>0:                    (IOPGR(IDAT,IATM,I),I=1,NP)
!----------
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..END OF GENLN2 INPUT (*ENDINP) [MANDATORY]
*ENDINP
!!!!!!! End of input data to GENLN2 !!!!!!!
```

```
************************************************
************************************************
**  GENLN2: GENERAL LINE-BY-LINE ATMOSPHERIC  **
**  TRANSMITTANCE AND RADIANCE MODEL          **
**  VERSION 3.0   D.P. EDWARDS   27/02/91     **
**  (C) COPYRIGHT 1991 UCAR/NCAR              **
**  ALL RIGHTS RESERVED                       **
**  GENLN2 SOFTWARE AND RELATED MATERIALS     **
**  MAY BE USED ONLY UNDER AN EXECUTED VALID  **
**  LICENCE AGREEMENT                         **
************************************************
************************************************

DATE (DAY.MON.YR): 10.12.91

*************** CHECK INPUT DATA FOR ERRORS ***************

&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&

*************** INPUT DATA SUCCESSFULLY READ ***************

*************** SUMMARY OF INPUT DATA ***************

TITLE OF THIS RUN :- ISAMS CO2 Ch7.1 Response

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

LINE AND CROSS-SECTION DATA
***************************
 1 LINE DATA FILE(S) WILL BE USED
FILE NO.  1 FILENAME ex2_hitlin_op.dat
 1 GAS(ES) TO BE READ, MOLEC ID NO(S):-     2
GAS LINE VERSION(S) TO BE CHOSEN:-         11
LINE MIXING SWITCHED ON
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

WAVENUMBER GRID
***************
TOTAL WAVENUMBER RANGE CONSIDERED         565.000 -    665.000 cm-1
PASSBAND (INTEGRATION) WAVENUMBER RANGE   590.000 -    640.000 cm-1
THIS CONSISTS OF    50 INTERVALS OF AVERAGE WAVENUMBER WIDTH     1.000 cm-1
EACH INTERVAL WILL BE DIVIDED INTO   2000 FINE MESHES FOR THE TRANSMITTANCE CALCULATION.
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

TRANSMITTANCE CALCULATION
*************************
THE LINE ABSORPTION IN A RANGE OF   1.000 cm-1 EITHER SIDE OF THE WIDEMESH INTERVAL WILL BE TREATED EXPLICITLY.
THE WING ABSORPTION DUE TO LINES LYING IN THE RANGE   1.000 -   25.000 cm-1
EITHER SIDE OF THE WIDEMESH INTERVAL WILL BE INCLUDED.
THE CONTINUUM ABSORPTION WILL BE INCLUDED FOR APPROPRIATE PATHS.
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

PATH DATA
*********
PATH  FILE  GAS ID  ISO ID  AMT kg.moles/cm2      T K      P atm  PARTP atm    VEL m/s  LINESHAPE  CONTINUUM
-------------------------------------------------------------------------------------------------------------
   1     1       2       0          3.063E-09  290.000  2.496E-02  2.496E-02  0.000E+00   VOIGTCO2    CON
   2     1       2       0          7.658E-09  290.000  6.242E-02  6.242E-02  0.000E+00   VOIGTCO2    CON
```

```
 !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

 SPECTRA WILL BE INTEGRATED OVER THE WIDEMESH INTERVALS.
 !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

 *************** CALCULATION BEGINS ***************

 &&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&


 *************** ELAPSED CPU TIME:   0:37:37.77 ***************


 *************** CALCULATION COMPLETE. ***************


 !!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

 INTEGRATED PATH TRANSMITTANCES
 ******************************

 *** PATH NO.    1 ***
 LINE DATA FROM FILE NO.  1 FILENAME: ex2_hitlin_op.dat
 TITLE: Limb example calculation
 INTERVAL  LOW BDY cm-1  UPP BDY cm-1  FINE MESHES     TRANSMITTANCE    LINES READ
 ---------------------------------------------------------------------------------
        1       590.000       591.000         2000       .998548E+00            38
        2       591.000       592.000         2000       .999784E+00            48
        3       592.000       593.000         2000       .998288E+00            47
etc.

       48       637.000       638.000         2000       .993600E+00           114
       49       638.000       639.000         2000       .971647E+00           111
       50       639.000       640.000         2000       .969189E+00            80
 TOTAL NUMBER OF LINES                                                        7353
 AVERAGE VALUE OVER PASSBAND                             .992088E+00

 *** PATH NO.    2 ***
 LINE DATA FROM FILE NO.  1 FILENAME: ex2_hitlin_op.dat
 TITLE: Limb example calculation
 INTERVAL  LOW BDY cm-1  UPP BDY cm-1  FINE MESHES     TRANSMITTANCE    LINES READ
 ---------------------------------------------------------------------------------
        1       590.000       591.000         2000       .996351E+00            38
        2       591.000       592.000         2000       .999385E+00            48
        3       592.000       593.000         2000       .995749E+00            47
etc.

       48       637.000       638.000         2000       .983032E+00           114
       49       638.000       639.000         2000       .929975E+00           111
       50       639.000       640.000         2000       .924717E+00            80
 TOTAL NUMBER OF LINES                                                        7353
 AVERAGE VALUE OVER PASSBAND                             .980560E+00


 *************** END OF DATA OUTPUT ***************

 *************** GRAPHICS FILE WRITTEN TO: ex3_genln2_opsr.dat                                ***************
```

```
 ***********************************************
 *                PROGRAM PMRFIL:              *
 * PROGRAM TO CREATE A PMR TRANSMITTANCE FILTER *
 ***********************************************
 **Q** Name of GENLN2 output file to read? :
ex3_genln2_opsr.dat
 **Q** How many gas cells (paths) approximate the the PMR cycle? :
2
 ***** CELL NO.  1 *****
 **Q** Enter path number and weighting coefficient :
1,    1
 ***** CELL NO.  2 *****
 **Q** Enter path number and weighting coefficient :
2,   -1
 *****  100000 TOTAL FINE MESH POINTS *****
 **Q** Enter filename of PMR filter output file :
ex3_pmrfil_op.dat
 **Q** Enter maximum absolute transmittance to count as non-zero :
0.0001
 **Q** Enter maximum no. of fine mesh per wide mesh interval:
2000
 **Q** Enter maximum no. of wide mesh intervals :
70
 **Q** Enter the maximum width of wide mesh interval [cm-1] :
1.0
 MINIMUM PTS FOR ZERO SECTION =     5:
 INTERVALS O/P =  112  MAX FINE MESH POINTS/INTERVAL =  2000
 MINIMUM PTS FOR ZERO SECTION =     6:
 INTERVALS O/P =  104  MAX FINE MESH POINTS/INTERVAL =  2000
 MINIMUM PTS FOR ZERO SECTION =     7:
 INTERVALS O/P =  102  MAX FINE MESH POINTS/INTERVAL =  2000
 MINIMUM PTS FOR ZERO SECTION =     8:
 INTERVALS O/P =  100  MAX FINE MESH POINTS/INTERVAL =  2000
 MINIMUM PTS FOR ZERO SECTION =     9:
 INTERVALS O/P =   98  MAX FINE MESH POINTS/INTERVAL =  2000
 MINIMUM PTS FOR ZERO SECTION =    10:
 INTERVALS O/P =   96  MAX FINE MESH POINTS/INTERVAL =  2000
etc.

 INTERVALS O/P =   75  MAX FINE MESH POINTS/INTERVAL =  2000
 MINIMUM PTS FOR ZERO SECTION =   127:
 INTERVALS O/P =   75  MAX FINE MESH POINTS/INTERVAL =  2000
 MINIMUM PTS FOR ZERO SECTION =   140:
 INTERVALS O/P =   73  MAX FINE MESH POINTS/INTERVAL =  2000
 MINIMUM PTS FOR ZERO SECTION =   154:
 INTERVALS O/P =   73  MAX FINE MESH POINTS/INTERVAL =  2000
 MINIMUM PTS FOR ZERO SECTION =   170:
 INTERVALS O/P =   72  MAX FINE MESH POINTS/INTERVAL =  2000
 MINIMUM PTS FOR ZERO SECTION =   187:
 INTERVALS O/P =   71  MAX FINE MESH POINTS/INTERVAL =  2000
 MINIMUM PTS FOR ZERO SECTION =   206:
 INTERVALS O/P =   67  MAX FINE MESH POINTS/INTERVAL =  2000
 MINIMUM PTS FOR ZERO SECTION =   206:
 INTERVALS O/P =   67  MAX FINE MESH POINTS/INTERVAL =  2000
 *****   96644 TOTAL FINE MESH POINTS FOR CALCULATION *****
```

```
!
! ***********************************************
! *                PROGRAM PMRFIL:              *
! * PROGRAM TO CREATE A PMR TRANSMITTANCE FILTER *
! ***********************************************
!
! NO. OF CELLS USED TO APPROXIMATE PMR CYCLE     =     2
! *****  CELL NO.    1   *****
! GENLN2 PATH NO. =  1   CELL WEIGHT =   1.0000
! *****  CELL NO.    2   *****
! GENLN2 PATH NO. =  2   CELL WEIGHT =  -1.0000
! MAXIMUM ABSOLUTE TRANSMITTANCE THAT
! COUNTS AS NON-ZERO                             =    .0001
! MINIMUM NO. OF ZERO POINTS FOR A ZERO WIDEMESH =   206
! MAXIMUM NO. OF FINE MESH POINTS PER WIDE MESH  =  2000
!
! Format for each wide mesh:
! Lower wn bdy, Upper wm bdy, No fine meshes/wide mesh, Zero section flag
! If Zero section flag is 1, there follows a vale of H(v) at each fine
! wn grid point.
!
     67                                    ! Total number of wide meshes
    590.1710    590.7660    1190 1
  1.003E-04  1.007E-04  1.009E-04  1.010E-04  1.010E-04  1.009E-04
  1.007E-04  1.005E-04  1.006E-04  1.010E-04  1.017E-04  1.028E-04
  1.038E-04  1.049E-04  1.058E-04  1.067E-04  1.073E-04  1.079E-04
etc.
  1.103E-04  1.096E-04  1.088E-04  1.083E-04  1.076E-04  1.070E-04
  1.065E-04  1.059E-04  1.054E-04  1.048E-04  1.044E-04  1.038E-04
  1.033E-04  1.028E-04  1.024E-04  1.019E-04  1.014E-04  1.009E-04
  1.005E-04  1.000E-04  9.960E-05
    590.7660    590.9360       1 0
    590.9360    591.1535     435 1
  9.972E-05  1.017E-04  1.034E-04  1.048E-04  1.059E-04  1.069E-04
  1.078E-04  1.084E-04  1.090E-04  1.096E-04  1.101E-04  1.106E-04
  1.112E-04  1.116E-04  1.122E-04  1.128E-04  1.134E-04  1.142E-04
etc.
  1.360E-04  1.317E-04  1.292E-04  1.277E-04  1.262E-04  1.244E-04
  1.220E-04  1.193E-04  1.161E-04  1.132E-04  1.106E-04  1.079E-04
  1.054E-04  1.028E-04  1.006E-04  9.847E-05
    591.1535    591.3775       1 0
    591.3775    591.5090     263 1
  9.769E-05  1.001E-04  1.022E-04  1.038E-04  1.044E-04  1.038E-04
  1.017E-04  9.763E-05  9.125E-05  8.112E-05  6.998E-05  5.805E-05
  4.762E-05  4.107E-05  4.071E-05  4.667E-05  5.698E-05  6.890E-05
etc.
  4.715E-05  4.494E-05  5.263E-05  6.598E-05  8.148E-05  9.584E-05
  1.073E-04  1.160E-04  1.203E-04  1.220E-04  1.217E-04  1.201E-04
  1.175E-04  1.139E-04  1.104E-04  1.068E-04  1.031E-04  9.954E-05
etc.

    639.9670    639.9995      65 1
  1.842E-02  1.820E-02  1.801E-02  1.783E-02  1.765E-02  1.748E-02
  1.731E-02  1.713E-02  1.698E-02  1.683E-02  1.668E-02  1.653E-02
  1.637E-02  1.624E-02  1.610E-02  1.597E-02  1.584E-02  1.570E-02
  1.558E-02  1.546E-02  1.534E-02  1.522E-02  1.510E-02  1.499E-02
  1.488E-02  1.477E-02  1.467E-02  1.455E-02  1.445E-02  1.435E-02
  1.425E-02  1.416E-02  1.406E-02  1.396E-02  1.386E-02  1.377E-02
  1.368E-02  1.359E-02  1.349E-02  1.341E-02  1.333E-02  1.324E-02
  1.316E-02  1.308E-02  1.300E-02  1.292E-02  1.285E-02  1.277E-02
  1.269E-02  1.261E-02  1.254E-02  1.247E-02  1.240E-02  1.232E-02
  1.225E-02  1.218E-02  1.212E-02  1.205E-02  1.199E-02  1.191E-02
  1.185E-02  1.179E-02  1.173E-02  1.167E-02  1.160E-02  1.154E-02
! TOTAL NO. OF FINE MESHES FOR CALULATION        =   96644
```

```
!                    ******************************************
!                    *                                        *
!                    *          PROGRAM GENLN2: INPUT FILE    *
!                    *          --------------------------    *
!                    *  INPUT FILE FOR THE GENLN2 LINE-BY-LINE *
!                    *  COMPUTER MODEL. CALCULATES ATMOSPHERIC *
!                    *  TRANSMITTANCE AND RADIANCE.            *
!                    *  VERSION 3.0: D.P. EDWARDS 21/08/90     *
!                    *                                        *
!                    ******************************************
!                                                        INPUT PARAMETER NAME
!-----------------------------------------------------------------------------
!..TITLE INFOMATION AND SUMMARY OUTPUT SPECIFICATION FOR THIS GENLN2 RUN
!..(*TITLES) [MANDATORY]
*TITLES
!
!      1A. Title of this GENLN2 run (40 characters MAX) :                TITLE
'PMR example calculation'
!
!      2A. Passband average spectral values only are printed in
!          formatted summary output file if logical is set true:         AVER
!      2B. Mixing table not printed if logical is set true:              MXER
.TRUE., .TRUE.
!
!      Data to be printed in the formatted summary output file is
!      specified by the IDAT parameter for the following categories:-
!      IDAT = 1  Path integrated transmittance spectrum.
!           = 2  Mixed path integrated transmittance spectrum.
!           = 3  Radiating atmosphere layer integrated
!                transmittance and radiance spectra.
!      The following section is repeated for each required IDAT.
!----------
!      3A. Index (1,2 or 3 above):                                       IDAT
3
!
!      If  IDAT = 1 or IDAT = 2:
!      4A. No. of paths or mixed paths to be printed: NP;
!          if all paths are to be print set NP<0.
!      Else if IDAT=3:
!      4A. Atmosphere no. for printing:                                  IATM
!          if all atmospheres are to be printed set IATM<0.
!      4B. no. of layers to be printed:                                    NP
!          if all layers are to be printed set NP<0.
1,1
!
!      For all IDAT:
!      5A. List of path, mixed path or layer nos. for printing;
!          only required if NP>0:                   (IOPDT(IDAT,IATM,I),I=1,NP)
40
!----------
3
2,1
0
!----------
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..THE GAS LINE DATA FILE(S) TO BE USED (*GASFIL) [MANDATORY]
*GASFIL
!
!      1A. No. of line data files to be read:                           NFILE
!      1B. Machine specifier, determines record length:                  MACH
!          MACH=1: 4 byte/word, OPEN RECL in words (eg. VAX, ANSII stand)
!          MACH=2: 4 byte/word, OPEN RECL in bytes (eg. IBM RISC)
!          MACH=3: 8 byte/word, OPEN RECL in bytes (eg. CRAY)
!          This should be the same as was used in HITLIN
1,2
!
!      For each file (IFILE=1,NFILE) 4 input records
!----------
!      2A. Filename of line data file:                                FNAM(IFILE)
'ex2_hitlin_op.dat'
!
!      3A. No. of gases to be read from this file:                    NGAS(IFILE)
2
!
!      4A. Molecular ID's of the gas(es) to be read:
!                                      (LGASES(IFILE,IGAS),IGAS=1,NGAS(IFILE))
2, 3
!
!      5A. Line data version(s) to be chosen:
!                                      (LCHOSE(IFILE,IGAS),IGAS=1,NGAS(IFILE))
11, 10
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..LINE COUPLING CALCULATION FOR FLAGGED LINES ON THE DATABASE (*LINMIX)
!..[NOT MANDATORY]
*LINMIX
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..CALCULATION OF SPECTRA CONVOLED WITH RADIOMETER RESPONSE FILTER (*RADIOM)
!..[MANDATORY if one of *USEGRD, *GRDFIL or *DEFGRD is not supplied]
*RADIOM
!
!      1A. The wavenumber range either side of a wide mesh interval for
!          which a fine grid line-by-line calculation is performed (cm-1):  FEXC
!      1B. the wavenumber range either side of a wide mesh interval
!          outside of which lines are not considered (cm-1):              FWIND
!      1C. the width of the wide mesh interval to be used in the wing
!          regions either side of the passband (cm-1):                   DELWNG
1.0,   25.0,    1.0
!
!      2A. The filename of the radiometer response profile:               RESFI
'ex3_pmrfil_op.dat'
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..PATH PARAMETERS READ FROM EXTERNAL FILE, EG. LAYERS OUTPUT FILE (*PTHFIL)
*PTHFIL
!
!      1A. File name of external path parameter file:                     PFNAM
'ex2_layers_op.dat'
!
!      File PFNAM then contains the same information as the
!      *PTHPAR section beginning with input record 2
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..MIXING PATHS TO FORM ATMOSPHERIC MIXED PATHS (*MIXING) [NOT MANDATORY]
*MIXING
!
!      1A. No. of mixed paths to be calculated:                           NPMIX
20
!
!      Mixing table is of length NPATH and depth NPMIX:
!      (remember NPATH is the sum of the number of paths read
!      in the *PTHPAR and the *PTHFIL sections)
!      The required mixing table parameters are:-
!      2A. The mixed path index:                                          IPMIX
!      2B. the mixing table:                  (TABMIX(IPATH,IPMIX),IPATH=1,NPATH))
!      Each new mixed path must begin a new line, and the
```

```
!       input field must not exceed 130 characters.
!
  1  ROT0    1 ROT19   ROT0    1 ROT19
  2  ROT1    1 ROT18   ROT1    1 ROT18
  3  ROT2    1 ROT17   ROT2    1 ROT17
  4  ROT3    1 ROT16   ROT3    1 ROT16
  5  ROT4    1 ROT15   ROT4    1 ROT15
  6  ROT5    1 ROT14   ROT5    1 ROT14
  7  ROT6    1 ROT13   ROT6    1 ROT13
  8  ROT7    1 ROT12   ROT7    1 ROT12
  9  ROT8    1 ROT11   ROT8    1 ROT11
 10  ROT9    1 ROT10   ROT9    1 ROT10
 11  ROT10   1 ROT9    ROT10   1 ROT9
 12  ROT11   1 ROT8    ROT11   1 ROT8
 13  ROT12   1 ROT7    ROT12   1 ROT7
 14  ROT13   1 ROT6    ROT13   1 ROT6
 15  ROT14   1 ROT5    ROT14   1 ROT5
 16  ROT15   1 ROT4    ROT15   1 ROT4
 17  ROT16   1 ROT3    ROT16   1 ROT3
 18  ROT17   1 ROT2    ROT17   1 ROT2
 19  ROT18   1 ROT1    ROT18   1 ROT1
 20  ROT19   1 ROT0    ROT19   1 ROT0
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..RADIANCE CALCULATION (*RADNCE) [NOT MANDATORY]
*RADNCE
!
!       1A. No. of radiating atmospheres to be calculated:                  NATM
2
!       For each atmosphere (IATM=1,NATM) 3 input records
!----------
!       Layer table data consists of the following:-
!       2A. The radiating atmosphere index:                                 IATM
!       2B. the viewing parameter:                                   IVIEW(IATM)
!       2C. the layer emission parameter:                             IEMS(IATM)
!       2D. the no. of layers in the atmosphere:                      NLAY(IATM)
!       2E. path or mixed path specifer for total layer absorption:  LAYSP(IATM)
!       2F. the path (LAYSP(IATM)=1) or mixed path nos.(LAYSP(IATM)=2)
!           to be used to specify the layer total absorption in order
!           of radiation travel:            (LAYER(ILAY,IATM),ILAY=1,NLAY(IATM))
! *** atmospheric radiance ***
1, 1, 1, 40, 2
20 19 18 17 16 15 14 13 12 11 10 9 8 7 6 5 4 3 2 1
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
!
!       If IVIEW(IATM)=2 then the initiating surface parameters are supplied:
!       3A. Atmospheric boundary temperature (K):                     TBDY(IATM)
!       3B. temperature of the initiating surface:                   TINIT(IATM)
!       3C. emissivity of initiating surface:                        EMSTY(IATM)
!TBDY(1), TINIT(1), EMSTY(1)
!
!       If IEMS(IATM)=2 different paths/mixed paths can to be used for
!       layer emission to those used for layer transmittance:
!       4A. path or mixed path specifer for emission layer absorption:LEMSP(IATM)
!       4B. the path (LEMSP(IATM)=1) or mixed-path nos.(LEMSP(IATM)=2)
!           to be used to specify the layer emission in order
!           in order of radiation travel:   (LAYEMS(ILAY,IATM),ILAY=1,NLAY(IATM))
!----------
! *** reference black-body radiance ***
2, 2, 1, 0, 1
!
0.0,  290.0,  1.0
!----------
!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..INTEGRATION SWITCH (*INTEGN) [NOT MANDATORY]
*INTEGN
!       Logical switch. When present the transmittance and radiance
!       spectra are integrated over each wide mesh interval.
!!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..UNFORMATTED OUTPUT FILE SPECIFICATION (*OUTPUT) [NOT MANDATORY]
*OUTPUT
!
!       1A. File name of output file:                                       OPFNAM
'ex3_genln2_ops.dat'
!
!       Data to be output is specified by IDAT parameter
!       for the following categories:-
!       IDAT= 1  Path point transmission spectrum;
!           = 2  Path integrated transmission spectrum;
!           = 3  Mixed path point transmission spectrum;
!           = 4  Mixed path integrated transmission spectrum;
!           = 5  Layer point transmission spectrum;
!           = 6  Layer integrated transmission spectrum;
!           = 7  Layer point radiance spectrum;
!           = 8  Layer integrated radiance spectrum.
!       The following section is repeated for each required IDAT.
!----------
!       2A. Index (1 thro' 8 above):                                        IDAT
8
!
!       For IDAT = 1, 2, 3 or 4:
!       3A. no. of paths or mixed paths to be output:                       NP
!           if all paths are to be output set NP<0.
!       For IDAT = 5, 6, 7 or 8:
!       3A. atmosphere no. for output:                                      IATM
!           if all atmospheres are to be output set IATM<0.
!       3B. no. of layers to be output:                                     NP
!           if all layers are to be output set NP<0.
1,1
!
!       For all IDAT:
!       4A. List of path, mixed path or layer nos. for output;
!           only required if NP>0:                   (IOPGR(IDAT,IATM,I),I=1,NP)
40
!----------
8
2,1
0
!----------
!!!!!! End of section !!!!!!!
!-----------------------------------------------------------------------------
!..END OF GENLN2 INPUT (*ENDINP) [MANDATORY]
*ENDINP
!!!!!!! End of input data to GENLN2 !!!!!!!
```

```
************************************************
************************************************
**  GENLN2: GENERAL LINE-BY-LINE ATMOSPHERIC  **
**  TRANSMITTANCE AND RADIANCE MODEL          **
**  VERSION 3.0   D.P. EDWARDS   27/02/91     **
**  (C) COPYRIGHT 1991 UCAR/NCAR              **
**  ALL RIGHTS RESERVED                       **
**  GENLN2 SOFTWARE AND RELATED MATERIALS     **
**  MAY BE USED ONLY UNDER AN EXECUTED VALID  **
**  LICENCE AGREEMENT                         **
************************************************
************************************************



DATE (DAY.MON.YR): 10.12.91


*************** CHECK INPUT DATA FOR ERRORS ***************

&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&


*************** INPUT DATA SUCCESSFULLY READ ***************

*************** SUMMARY OF INPUT DATA ***************

TITLE OF THIS RUN :- PMR example calculation

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

LINE AND CROSS-SECTION DATA
***************************
 1 LINE DATA FILE(S) WILL BE USED
FILE NO.  1 FILENAME ex2_hitlin_op.dat
 2 GAS(ES) TO BE READ, MOLEC ID NO(S):-     2    3
GAS LINE VERSION(S) TO BE CHOSEN:-         11   10
LINE MIXING SWITCHED ON
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

WAVENUMBER GRID
***************
TOTAL WAVENUMBER RANGE CONSIDERED         565.000 -    665.000 cm-1
PASSBAND (INTEGRATION) WAVENUMBER RANGE   590.171 -    640.000 cm-1
THIS CONSISTS OF    67 INTERVALS OF AVERAGE WAVENUMBER WIDTH      .744 cm-1
EACH INTERVAL WILL BE DIVIDED INTO THE NUMBER OF FINE MESHES SPECIFIED IN THE RADIOMETER RESPONSE DATA.
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

TRANSMITTANCE CALCULATION
*************************
THE LINE ABSORPTION IN A RANGE OF   1.000 cm-1 EITHER SIDE OF THE WIDEMESH INTERVAL WILL BE TREATED EXPLICITLY.
THE WING ABSORPTION DUE TO LINES LYING IN THE RANGE    1.000 -    25.000 cm-1
EITHER SIDE OF THE WIDEMESH INTERVAL WILL BE INCLUDED.
THE CONTINUUM ABSORPTION WILL BE INCLUDED FOR APPROPRIATE PATHS.
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

PATH DATA
*********
```

```
PATH  FILE  GAS ID  ISO ID  AMT kg.moles/cm2      T K     P atm  PARTP atm    VEL m/s  LINESHAPE  CONTINUUM
------------------------------------------------------------------------------------------------------------

    1    1       2       0         1.637E-06  226.728  1.151E-02  3.799E-06  0.000E+00   VOIGTCO2   CON
    2    1       2       0         6.165E-07  227.525  1.051E-02  3.467E-06  0.000E+00   VOIGTCO2   CON
    3    1       2       0         7.719E-07  228.541  9.357E-03  3.088E-06  0.000E+00   VOIGTCO2   CON
    4    1       2       0         5.015E-07  230.091  7.975E-03  2.632E-06  0.000E+00   VOIGTCO2   CON
    5    1       2       0         3.647E-07  232.538  6.949E-03  2.293E-06  0.000E+00   VOIGTCO2   CON
    6    1       2       0         2.781E-07  235.145  6.082E-03  2.007E-06  0.000E+00   VOIGTCO2   CON
    7    1       2       0         2.180E-07  237.731  5.331E-03  1.759E-06  0.000E+00   VOIGTCO2   CON
    8    1       2       0         1.741E-07  240.294  4.679E-03  1.544E-06  0.000E+00   VOIGTCO2   CON
    9    1       2       0         1.404E-07  242.905  4.100E-03  1.353E-06  0.000E+00   VOIGTCO2   CON
   10    1       2       0         2.036E-07  247.185  3.330E-03  1.099E-06  0.000E+00   VOIGTCO2   CON
   11    1       2       0         1.357E-07  252.986  2.509E-03  8.281E-07  0.000E+00   VOIGTCO2   CON
   12    1       2       0         9.381E-08  258.516  1.926E-03  6.357E-07  0.000E+00   VOIGTCO2   CON
   13    1       2       0         6.606E-08  263.999  1.488E-03  4.909E-07  0.000E+00   VOIGTCO2   CON
   14    1       2       0         4.734E-08  269.044  1.156E-03  3.815E-07  0.000E+00   VOIGTCO2   CON
   15    1       2       0         3.466E-08  270.658  9.000E-04  2.970E-07  0.000E+00   VOIGTCO2   CON
   16    1       2       0         5.319E-08  266.326  6.057E-04  1.999E-07  0.000E+00   VOIGTCO2   CON
   17    1       2       0         2.639E-08  254.698  3.184E-04  1.051E-07  0.000E+00   VOIGTCO2   CON
   18    1       2       0         1.301E-08  240.962  1.620E-04  5.347E-08  0.000E+00   VOIGTCO2   CON
   19    1       2       0         6.285E-09  227.289  7.957E-05  2.626E-08  0.000E+00   VOIGTCO2   CON
   20    1       2       0         4.253E-09  211.467  3.126E-05  1.031E-08  0.000E+00   VOIGTCO2   CON
   21    1       3       0         3.277E-08  226.730  1.151E-02  7.609E-08  0.000E+00   VOIGT      NOCON
   22    1       3       0         1.269E-08  227.527  1.050E-02  7.155E-08  0.000E+00   VOIGT      NOCON
   23    1       3       0         1.645E-08  228.546  9.351E-03  6.593E-08  0.000E+00   VOIGT      NOCON
   24    1       3       0         1.117E-08  230.097  7.972E-03  5.860E-08  0.000E+00   VOIGT      NOCON
   25    1       3       0         8.348E-09  232.543  6.947E-03  5.251E-08  0.000E+00   VOIGT      NOCON
   26    1       3       0         6.523E-09  235.150  6.080E-03  4.708E-08  0.000E+00   VOIGT      NOCON
   27    1       3       0         5.172E-09  237.730  5.331E-03  4.174E-08  0.000E+00   VOIGT      NOCON
   28    1       3       0         4.122E-09  240.293  4.680E-03  3.657E-08  0.000E+00   VOIGT      NOCON
   29    1       3       0         3.310E-09  242.902  4.101E-03  3.191E-08  0.000E+00   VOIGT      NOCON
   30    1       3       0         4.636E-09  247.159  3.334E-03  2.511E-08  0.000E+00   VOIGT      NOCON
   31    1       3       0         2.833E-09  252.928  2.516E-03  1.748E-08  0.000E+00   VOIGT      NOCON
   32    1       3       0         1.716E-09  258.456  1.932E-03  1.175E-08  0.000E+00   VOIGT      NOCON
   33    1       3       0         1.052E-09  263.928  1.493E-03  7.929E-09  0.000E+00   VOIGT      NOCON
   34    1       3       0         6.251E-10  268.969  1.161E-03  5.157E-09  0.000E+00   VOIGT      NOCON
   35    1       3       0         3.697E-10  270.656  9.042E-04  3.261E-09  0.000E+00   VOIGT      NOCON
   36    1       3       0         4.071E-10  266.741  6.212E-04  1.706E-09  0.000E+00   VOIGT      NOCON
   37    1       3       0         1.192E-10  255.225  3.262E-04  5.231E-10  0.000E+00   VOIGT      NOCON
   38    1       3       0         3.643E-11  241.444  1.659E-04  1.635E-10  0.000E+00   VOIGT      NOCON
   39    1       3       0         9.990E-12  228.137  8.307E-05  5.121E-11  0.000E+00   VOIGT      NOCON
   40    1       3       0         3.562E-12  211.583  3.158E-05  8.882E-12  0.000E+00   VOIGT      NOCON
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

MIXING TABLE DATA
*****************
MIXING TABLE IS OF LENGTH  40 PATH(S) AND DEPTH  20 MIXED PATH(S)

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

RADIANCE DATA
*************
CALCULATIONS WILL BE PERFORMED FOR   2 RADIATING ATMOSPHERE(S)

ATMOSPHERE  NO LAY PTH/MIX   PATH/MIXED PATH NOS TO BE USED FOR LAYER TRANSMITTANCE IN ORDER OF THE DIRECTION OF RADIATION TRAVEL
------------------------------------------------------------------------------------------------------------------------------------

         1      40        2      20  19  18  17  16  15  14  13  12  11  10   9   8   7   6   5   4   3   2   1   1   2   3   4   5
```

```
                                6   7   8   9  10  11  12  13  14  15  16  17  18  19  20
VIEWING  PARAMETER =  1

         2       0       1
VIEWING  PARAMETER =  2   ATMOSPHERIC BOUNDARY TEMP. (K) =      .000   SURFACE EMITTANCE =  1.00000   SURFACE TEMP. (K) =  290.000
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

FINE MESH SPECTRA WILL BE CONVOLVED WITH THE RADIOMETER RESPONSE FROM FILE:
ex3_pmrfil_op.dat
AND THEN INTEGRATED OVER THE WIDE MESH INTERVALS.
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

*************** CALCULATION BEGINS ***************

&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&&


*************** ELAPSED CPU TIME:   1:15:59.37 ***************


*************** CALCULATION COMPLETE. ***************
!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!

INTEGRATED ATMOSPHERIC LAYER TRANSMITTANCES AND BOUNDARY RADIANCES
******************************************************************

*** ATMOSPHERE   1 ***

*** LAYER NO.   40 ***                               TRANSMITTANCE    BDY RADIANCE
                                                                    W/(m2.st.cm-1)
AVERAGE VALUES OVER PASSBAND                           .910181E-01      .703157E-01

*** ATMOSPHERE   2 ***

*** LAYER NO.    0 ***                               TRANSMITTANCE    BDY RADIANCE
                                                                    W/(m2.st.cm-1)
AVERAGE VALUES OVER PASSBAND                           .100000E+01      .137011E+00


*************** END OF DATA OUTPUT ***************

*************** GRAPHICS FILE WRITTEN TO: ex3_genln2_ops.dat                                ***************
```

```
##################################################
##################################################
##              PROGRAM BRIGHT                  ##
##              --------------                  ##
##  POST-PROCESSING PROGRAM FOR GENLN2:         ##
##  CONVOLVES TRANSMITTANCES/RADIANCES WITH     ##
##  A RADIOMETER WIDEBAND RESPONSE FUNCTION     ##
##  AND OPTIONALLY CONVERTS TO EQUIVALENT       ##
##  BRIGHTNESS TEMPERATURE                      ##
##  VERSION 3.0   D.P. EDWARDS   27/02/91       ##
##  (C) COPYRIGHT 1991 UCAR/NCAR                ##
##  ALL RIGHTS RESERVED                         ##
##  GENLN2 SOFTWARE AND RELATED MATERIALS MAY   ##
##  BE USED ONLY UNDER AN EXECUTED VALID        ##
##  LICENCE AGREEMENT                           ##
##################################################
##################################################


 **Q** Enter name of GENLN2 unformatted output file :
ex3_genln2_ops.dat
 **Q** Are wide mesh binned spectral values to be used? [Y/N] :
Y
 **Q** Enter name of channel response data file :
ex3_bright_res.dat
 **Q** Are path transmittances to be convolved? [Y/N] :
N
 **Q** Are mixed path transmittances to be convolved? [Y/N] :
N
 **Q** Are layer transmittances to be convolved? [Y/N] :
N
 **Q** Are layer radiances to be convolved? [Y/N] :
Y
 **Q** Are brightness temps to be calculated?  [Y/N] :
N
 **Q** Enter name of output file :
ex3_bright_op.dat
```

```
!
! ***********************************************************
! *  ISAMS Channel 7.1 Blocker Response (provitional data) *
! *                    Data is in ESDA                     *
! ***********************************************************
      'ISAMS'      71
        137       20.0
          1   590.3589      4.5322110E-03
          2   590.6191      4.2084819E-03
          3   591.1084      5.5033993E-03
          4   591.2586      8.0932342E-03
          5   591.7491      9.7118812E-03
          6   592.0026      6.1508580E-03
          7   592.3911      7.1220458E-03
          8   592.6450      7.7695046E-03
          9   593.1378      1.0035610E-02
         10   593.2810      6.7983167E-03
         11   593.7828      5.8271284E-03
         12   594.0381      1.0359339E-02
         13   594.4533      1.1977986E-02
         14   594.6849      8.0932342E-03
         15   595.1892      1.3920363E-02
etc.

        120   633.6009      3.1078018E-02
        121   634.1005      2.4603432E-02
        122   634.4006      2.6869537E-02
        123   634.9653      2.2984784E-02
        124   635.1295      1.9100033E-02
        125   635.7047      1.9423762E-02
        126   635.9971      1.9423762E-02
        127   636.4364      1.8128844E-02
        128   636.7296      1.5862739E-02
        129   637.1699      1.6186468E-02
        130   637.4637      1.4567821E-02
        131   637.9051      1.2949174E-02
        132   638.1996      1.2301716E-02
        133   638.6420      7.7695046E-03
        134   638.8079      9.0644220E-03
        135   639.3621      5.8271284E-03
        136   639.5377      8.7406924E-03
        137   639.9726      1.2625445E-02
```

```
**************************************************
**************************************************
**  BRIGHT: POST-PROCESSING PROGRAM FOR         **
**  GENLN2. CONVOLVES TRANSMITTANCES/RADIANCES  **
**  WITH RADIOMETER WIDEBAND RESPONSE FUNCTION  **
**  AND OPTIONALLY CONVERTS TO EQUIVALENT       **
**  BRIGHTNESS TEMPERATURE                      **
**  VERSION 3.0   D.P. EDWARDS   27/02/91       **
**  (C) COPYRIGHT 1991 UCAR/NCAR                **
**  ALL RIGHTS RESERVED                         **
**  GENLN2 SOFTWARE AND RELATED MATERIALS MAY   **
**  BE USED ONLY UNDER AN EXECUTED VALID        **
**  LICENCE AGREEMENT                           **
**************************************************
**************************************************


GENLN2 OUTPUT DATA FILENAME  : ex3_genln2_ops.dat

FILTER RESPONSE DATA FILENAME: ex3_bright_res.dat

TITLE OF GENLN2 RUN          : PMR example calculation


!
! ***********************************************************
! *  ISAMS Channel 7.1 Blocker Response (provitional data) *
! *                    Data is in ESDA                     *
! ***********************************************************

CONVOLVED LAYER RADIANCES
*************************
ATMOSPHERE NO.      LAYER NO.       CONVOLVED RADIANCE
                                      [W/(cm-1.sr.m2)]
-------------------------------------------------------------------------------
            1            40              7.15430E-02    ! S_atm
            2             0              1.37433E-01    ! S_BB      Eqn.A3.10
```

REFERENCES

Anderson, G. P., S. A. Clough, F. X. Kneizys, J. H. Chetwynd, and E. P. Shettle, *AFGL Atmospheric Constituent Profiles (0-120 km)*, AFGL-TR-86-0110, AFGL (OPI), Hanscom AFB, MA 01736, 1986.

Armstrong, B. H., Spectrum line profiles: the Voigt function, *J. Quant. Spectrosc. Radiat. Transfer* **7**, 66–88, 1967.

Ballard, J., W. B. Johnston, M. R. Gunson, and P. T. Wassell, Absolute absorption coefficient of $ClONO_2$ infrared bands at stratospheric temperature, *J. Geophys. Res.* **93**, 1659–1665, 1988.

Bignell, K., The infrared water vapor continuum, *Q. J. R. Meteorol. Soc.* **96**, 390–403, 1970.

Birnbaum, G., The shape of collision broadened lines from resonance to the far wings, *J. Quant. Spectrosc. Radiat. Transfer* **21**, 597–607, 1979.

Brown, L. R., C. B. Farmer, C. P. Rinsland, and R. A. Toth, Molecular line parameters for the atmospheric trace molecule spectroscopy experiment, *Appl. Opt.* **23**, 5154–5182, 1987.

Burch, D. E., *Continuum Absorption by H_2O*, **AFGL-TR-81-0300**, AFGL(OPI), Hanscom AFB, MA 01731, 1982.

Burch, D. E., and R. L. Alt, *Continuum Absorption by H_2O in the 700–1200 cm^{-1} and 2400 - 2800 cm^{-1} windows*, **AFGL-TR-84-0128**, AFGL (OPI), Hanscom AFB, MA 01731, 1984.

Cantrell, C. A., J. A. Davidson, A. H. McDaniel, R. E. Shetter, and J. G. Calvert, Infrared absorption cross-sections for N_2O_5, *Chem. Phys. Lett.* **148**, 358–363, 1988.

Clough, S. A., F. X. Kneizys, R. Davies, R. Gamache, and R. Tipping, Theoretical line shape for H_2O vapor; Application to the continuum, in *Atmospheric water vapor*, pp. 25–46, edited by A. Deepak et al., Academic, NY, 1980.

Clough, S. A., F. X. Kneizys, L. S. Rothman, and W. O. Gallery, Atmospheric spectral transmission and radiance: FASCOD1B, *SPIE Atmospheric Transmission* **277**, 152–166, 1981.

Clough, S. A., F. X. Kneizys, G. P. Anderson, E. P. Shettle, J. H. Chetwynd, L. W. Abreu, L. A. Hall, and R. D. Worsham, FASCOD3: Spectral simulation, in *IRS '88: Current problems in atmospheric radiation*, Proc. of IRS, Lille, France, 18–24 August 1988, edited by J. Lenoble and J. F. Geleyn, A. Deepak Publ., Va, 1989a.

Clough, S. A., F. X. Kneizys, and R. W. Davis, Line shape and the water vapor continuum, *Atmospheric Research* **23**, 229–241, 1989b.

Cousin, C., R. le Doucen, C. Boulet, and H. Henry, Temperature dependence of the absorption in the region beyond the 4.3 μm band head of CO_2. 2: N_2 and O_2 broadening, *Appl. Opt.* **24**, 3899–3907, 1985.

Edwards, D. P., *GENLN2: The New Oxford Line-by-Line Atmospheric Transmission/ Radiance Model*, **Memorandum 87.2.**, Dept. Atmospheric, Oceanic and Planetary Physics, University of Oxford, UK, 1987.

Edwards, D. P., Atmospheric transmittance and radiance calculations using line-by-line computer models, *SPIE Modeling of the Atmosphere*, **928** 94–116, 1988.

Edwards, D. P., and L. L. Strow, Spectral line shape considerations for limb temperature sounders, *J. Geophys. Res.* **96**, 20859–20868, 1991.

Elden, K., The refractive index of air, *Metrologia* **12**, 12, 1966.

Fischer, H., G. P. Anderson, T. v. Clarmann, S. A. Clough, M. T. Coffey, A. Goldman, and F. X. Kneizys, *Intercomparison of Transmittance and Radiance Algorithms (ITRA)*, **KfK 4349**, Kernforchungszentrun Karlsruhe, 1988.

Gamache, R. R., R. L. Hawkins, and L. S. Rothman, Total internal partition sums for atmospheric molecules in the temperature range 70–2005 K: Atmospheric linear molecules, *J. Mol. Spec.* **142**, 205–219, 1990.

Gebbie, H. A., Resonant absorption by water vapor polymers in the atmosphere, *Nature* **296**, 422–424, 1982.

Goody, R.M., and Y. L. Yung, *Atmospheric Radiation, Theoretical Basis*, Oxford University Press, 1989.

Grant, W. B., Water vapor absorption coefficients in the 8–13 μm spectral region. A critical review, *Appl. Opt.* **29**, 451–462, 1990.

Hinderling, J., M. W. Sigrist, and F. K. Kneubuhl, Laser-photoacoustic spectroscopy of water-vapor continuum and line absorption in the 8 to 14 μm atmospheric window, *Infrared Phys.* **27**, 63–120, 1987.

Humlicek, J., Optimized computation of the Voigt and complex probability functions, *J. Quant. Spectrosc. Radiat. Transfer* **27**, 437–444, 1982.

Husson, N., A. Chedin, N. A. Scott, D. Bailly, G. Graner, N. Lacome, A. Levy, C. Rossetti, G. Tarrago, C. Camy-Peyret, J.-M. Flaud, A. Bauer, J. M. Colmont, N. Monnanteuil, J. C. Hilico, G. Pierre, M. Loete, J. P. Champion, L. S. Rothman, L. R. Brown, G. Orton, P. Varanasi, C. P. Rinsland, M. A. H. Smith, and A. Goldman, The GEISA spectroscopic line parameters data bank in 1984, *Ann. Geophys.* **4**, 185–190, 1986.

Husson, N., B. Bonnet, N. A. Scott, and A. Chedin, *The GEISA data bank 1991 version*, Internal Note Laboratoire de Météorologie Dynamique du CNRS **No. 163**, Ecole Polytechnique, Palaiseau, France, 1991.

Kilsby, C. G., D. P. Edwards, R. W. Saunders, and J. S. Foot, Water vapor continuum absorption in the tropics; aircraft measurements and model comparisons, Accepted for publication in *Q. J. R. Meteorol. Soc.*, 1992.

Kneizys, F.X., E.P. Shettle, L. W. Abreu, J. H. Chetwynd, G. P. Anderson, W. O. Gallery, J. E. A. Selby, and S. A. Clough, *Users guide to LOWTRAN7*, **AFGL-TR-88-0177**, AFGL(OPI), Hanscom AFB, MA 01731, 1988.

Ma, Q., and R. H. Tipping, The atmospheric water continuum in the infrared: extension of the statistical theory of Rosenkranz, *J. Chem. Phys.* **93**, 7066–7075, 1990.

Massie, S. T., A. Goldman, D. G. Murcray, and J. C. Gille, Approximate absorption cross-sections of F12, F11, $ClONO_2$, HNO_3, CCl_4, CF_4, F21, F113, F114, and HNO_4, *Appl. Opt.* **24**, 3426–3427, 1985.

McDaniel, A. H., C. A. Cantrell, J. A. Davidson, R. E. Shetter, and J. G. Calvert, The temperature dependent, infrared absorption cross sections for the chloroflorocarbons: CFC–11, CFC–12, CFC–13, CFC–14, CFC–22, CFC–113, CFC–114, and CFC–115, *J. Atmos. Chem* **12**, 211-227, 1991.

Norton, R. H., and R. Beer, New apodizing functions for fourier spectrometry, *J. Opt. Soc. Am.* **66**, 259–264, 1976.

Poynter, R. L., and H. M. Pickett, Submillimeter, millimeter, and microwave spectral line catalog, *Appl. Opt.* **24**, 2235–2240, 1985.

Rinsland, C. P., R. Zander, J. S. Namkung, C. B. Farmer, and R. H. Norton, Stratospheric infrared continuum absorptions observed by the ATMOS instrument, *J. Geophys. Res.* **94**, 16303–16322, 1989.

Roscoe, H. K., and R. J. Wells, The variation of pressure, temperature and transmission within a pressure modulator: Measurements with a high-compression modulator, *J. Quant. Spectrosc. Radiat. Transfer* **141**, 259–285, 1989.

Rosenkranz, P. W., Shape of the 5 mm oxygen band in the atmosphere, *IEEE Trans. Antennas Propag.* **AP–23**, 498–506, 1975.

Rosenkranz, P. W., Pressure broadening of rotational bands. I: A statistical theory, *J. Chem. Phys.* **83**, 6139–6144, 1985.

Rosenkranz, P. W., Pressure broadening of rotational bands. II: Water vapor from 300–1100 cm^{-1}, *J. Chem. Phys.* **87**, 163–170, 1987.

Rothman, L. S., R. R. Gamache, A. Goldman, L. R. Brown, R. A. Toth, H. M. Pickett, R. L. Poynter, J.-M. Flaud, C. Camy-Peyret, A. Barbe, N. Husson, C. P. Rinsland, and M. A. H. Smith, The HITRAN database: 1986 edition, *Appl. Opt.* **26**, 4058–4097, 1987.

Saunders, R. W., and D. P. Edwards, Atmospheric transmittance for the AVHRR channels, *Appl. Opt.* **28**, 4154–4160, 1989.

Strow, L. L., and B. M. Gentry, Rotational collisional narrowing in an infrared CO_2 Q-branch, *J. Chem. Phys.* **84**, 1149–1156, 1986.

Strow, L. L., and D. Reuter, Effect of line mixing on atmospheric brightness temperatures near 15 μm, *Appl. Opt.* **27**, 872–878, 1988.

Suck, S. H., A. E. Wetmore, T. S. Chen, and J. L. Kassner, Role of various water clusters in IR absorption in the 8–14 μm window region, *Appl. Opt.* **21**, 1610–1614, 1982.

Taylor, F. W., Pressure Modulator Radiometry, in *Spectroscopic Techniques, Vol.III*, pp.137–196, Academic, San Diego, Calif., 1983.

Thomas, M. E., and R. J. Nordstrom, Line shape model for describing infrared absorption by water vapor, *Appl. Opt.* **24**, 3526–3530, 1985.

Timofeyev, Y. M., and M. V. Tonkov, Effect of the induced Oxygen absorption band on the transformation of radiation in the 6 μm region of the Earth's atmosphere, *Izvestiya, Atmospheric and Oceanic Phys.* **14**, 437–441, 1978.

Van Vleck, J. H., and D. L. Huber, Absorption, emission, and linebreadths: A semihistorical perspective, *Rev. Mod. Phys.* **49**, 939–959, 1977.

Varanasi, P., Infrared absorption by water vapor in the atmospheric window, *SPIE Modeling of the atmosphere* **928**, 213–230, 1988.