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Users Guide For SENTRAN7, Version 2.0

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13. ABSTRACT (Maximum 200 words)

SENTRAN7 is a user friendly interface system to LOWTRAN7 and MODTRAN. The code permits users to rapidly evaluate atmospheric conditions and path geometries. The main features of SENTRAN7 include:
(1) interactive entry of LOWTRAN7/MODTRAN input parameters and directives for their perturbation,
(2) intelligent generation of LOWTRAN7/MODTRAN input deck images, (3) autonomous post-processing of LOWTRAN7/MODTRAN outputs for data extraction, analysis and 3D graphical display, and (4) a help utility.

The thrust of the current effort is to incorporate new features and enhancements into SENTRAN7. The new code is called SENTRAN7, Version 2.0. The new features include: (1) the capability to impose random and percent perturbations by layer on user-defined profiles of atmospheric constituents, (2) a comprehensive error checking package that checks user-defined profiles of atmospheric constituents, (3) an option to save LOWTRAN/MODTRAN output as customized file names, and (4) a general purpose module that permits users to view the contents of files of their choosing.

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1 INTRODUCTION

1.1 Background and Purpose of Study

The Geophysics Directorate of the Phillips Laboratory (GP) has developed a number of computer codes to evaluate atmospheric transmittance and background radiance for a given atmospheric path and frequency region. The LOWTRAN7 model[1] and its predecessor LOWTRAN6[2], have been recognized by the DoD community as its standard for calculating atmospheric transmission and radiance at low spectral resolution. Recently, the development of the moderate resolution code MODTRAN[3] has increased in popularity given that the format of the input card images for MODTRAN is essentially the same as LOWTRAN7 and because users

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[1] Kneizys, F.X., Shettle, E.P., Abreu, L.W., Chetwynd, J.H., Anderson, G.P., Gallery, W.O., Selby, J.E.A, and Clough, S.A. (1988) *Users Guide to LOWTRAN7*, Air Force Geophysics Laboratory, Hanscom AFB, MA, AFGL-TR-88-0177, (ADA206773).

[2] Kneizys, F.X., Shettle, E.P., Gallery, W.O., Chetwynd, J.H., Abreu, L.W., Selby, J.E.A., Clough, S.A., and Fenn, R.W. (1983) *Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 6*, Air Force Geophysics Laboratory, Hanscom AFB, MA, AFGL-TR-83-0187, (ADA137796).

[3] Berk, A., Bernstein, L.S., and Robertson, D.C. (1989) *MODTRAN: A Moderate Resolution Model for LOWTRAN7*, Air Force Geophysics Laboratory, Hanscom AFB, MA, AFGL-TR-89-0122,(ADA214337).

can obtain results at spectral resolutions down to 2 cm^{-1}, instead of 20 cm^{-1} as with LOWTRAN7.

An important key to a successful utilization of LOWTRAN7 and MODTRAN is the accuracy of the input atmospheric data. In order for output from these codes to be useful, the corresponding input must be accurate. However, some atmospheric variables are inherently difficult to obtain or to predict accurately due to their fast variability. Unavoidable uncertainties occur in these variables regardless of how they are obtained. The effects of these uncertainties on LOWTRAN7 and MODTRAN computations must be critically evaluated if the results from these codes are to be meaningful and reliable.

In response to these needs, a systematic sensitivity analysis plan was developed for LOWTRAN6. The plan was to quantitatively, as well as qualitatively, evaluate variations in transmittances and radiances from LOWTRAN6 against perturbations in input atmospheric conditions. The plan eventually evolved into a computer software package, called SENTRAN (SENsitivity analysis plan for lowTRAN).[4] Since the development of the SENTRAN code, however, GP released LOWTRAN7 which contained revised formats for the input card images and additional parameters to characterize the atmospheric path. In 1991, SPARTA, Inc. was tasked to make SENTRAN comform with LOWTRAN7. The new computer code, called SENTRAN7[5], exhibits full compatibility with LOWTRAN7 and MODTRAN plus many new features to facilitate sensitivity analyses.

Since the release of SENTRAN7, prospective users have exercised the code and provided constructive feedback for possible improvements and enhancements. Thus, the focus of this effort was to incorporate as many of these suggestions into SENTRAN7 as possible.

1.2 Organization of the Report

This report consists of six chapters and four appendices. Chapter 2 describes the work performed in this effort, including the new features which have been added. Chapter 3 describes the steps required to install and run SENTRAN7 on a user's computer system. Chapter 4 contains a Users Guide which gives a general overview of SENTRAN7, along with a detailed description of how to use SENTRAN7. Chapter 5 is a Tutorial which leads the user through a series of brief exercises with SENTRAN7. The report is complete in itself, although much of the material in the

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[4] Tomiyama, K. and Hogan, M. (1988) *Sensitivity Evaluation Plan for LOWTRAN*, Department of Electrical Engineering, The Pennsylvania State University.

[5] Longtin, D.R., DePiero, N.L., Pagliughi, F.P., and Hummel, J.R. (1991) *SENTRAN7: The Sensitivity Analysis Package for LOWTRAN7 and MODTRAN*, Phillips Laboratory, Hanscom AFB, MA, PL-TR-91-2290(II), (ADA251595).

Users Guide and Tutorial is taken from the SENTRAN7 final report.[5] Conclusions and suggestions for further research are summarized in Chapter 6. Appendix A describes the input and output files used by SENTRAN7. Appendix B contains the source code changes made to LOWTRAN7 and MODTRAN. Appendix C is a Quick Reference Guide which contains brief summaries of SENTRAN7 commands and files that make up the SENTRAN7 package. Finally, Appendix D contains a flow chart of SENTRAN7's Graph and Analyze Module's program flow.

Familiarity with LOWTRAN7 and MODTRAN is presumed throughout this report. Therefore, the LOWTRAN7 Users Guide[1] and the MODTRAN Users Guide[3] should be used as companion guides for learning the SENTRAN7 system.

2 WORK PERFORMED ON SENTRAN7

This chapter describes specific tasks performed on SENTRAN7 during the current effort. In some cases, only brief overviews are given here. More complete explanations of how to use these options and features are given in the Users Guide.

2.1 Notations Used in This Report

The following notations are used in this report:

- Commands to be entered by the user within SENTRAN7 are set off by single quotation marks in this report, and appear in boldface and lower case (*e.g.,* **'help'**). The symbols '' are not entered as part of the command. Note that SENTRAN7 is case insensitive and, therefore, users can enter all commands in lower or upper case.

- File names appear in italics in this report (*e.g., TAPE7.OUT*). The file names are written in either upper or lower case, exactly as they would appear on a UNIX computer system, which is case sensitive. Note that if the user is operating SENTRAN7 on a UNIX computer system, all input and output files created by SENTRAN7 are in upper case. This is because SENTRAN7 internally converts all commands entered by the user to upper case and, therefore, accesses all file names within these commands as upper case file names. UNIX system users only need to be concerned with the file name case when accessing these files from outside of SENTRAN7. If running SENTRAN7 on a VAX/VMS computer system, all file names are in upper case.

- The word, RETURN, implies hitting the return or enter key on the user's keyboard.

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2.2   Brief Overview of SENTRAN7

SENTRAN7 is structured into a number of subprograms called modules. Each module performs a specific task to aid users in their sensitivity studies. These modules include:

- A Load/Save Module for loading and saving SENTRAN7 methodology files.
- A Define Perturbations Module for specifying detailed perturbation parameters for the Card 2C series.
- An Edit Module for specifying the values of parameters on LOWTRAN7 and MODTRAN card images, along with directions for their perturbation.
- A Compile Module for creating LOWTRAN7 and MODTRAN input files.
- A Select Module for selecting which transmission model to execute.
- A Run Module for executing the selected transmission model.
- A Graph and Analyze Module for extracting output data for data analysis and plotting.
- A View File Module for viewing files without exiting SENTRAN7.
- A Help Module for providing on-line help for SENTRAN7 users.

The following sections describe the changes made to SENTRAN7, Version 2.0. The methodology files created with the previous version of SENTRAN7 can still be used with SENTRAN7, Version 2.0, although the code will issue an error message when the methodology files are loaded.

2.3   Default to MODTRAN

Upon entering the code, SENTRAN7 now uses MODTRAN as its default target program. This change was implemented because the Geophysics Directorate does not plan to upgrade LOWTRAN7 in the future and because MODTRAN is gaining wider use among the scientific community. Users can still override the default execution mode in the SELECT LOWTRAN7/MODTRAN Module in the Main Menu.

2.4   Default to "LOG ON"

SENTRAN7 contains a "log" file feature that keeps a detailed track of all commands issued and error checking messages during a SENTRAN7 session. The information is written to a fixed file name, *SEN.LOG*.

Upon entering the code, SENTRAN7 now uses the log file feature as its default execution mode. Note that information on all actions are continuously written to the *SEN.LOG* file until the user closes it or until the users exits SENTRAN7. Thus, the *SEN.LOG* file can be come quite large during long SENTRAN7 sessions

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or when the SENTRAN7 error checking package (see Section 2.5) has identified many compilation errors. Users can deactivate this feature by typing 'log' from the Main Menu (see the LOG command in the Users Guide).

2.5 Error Checking on User-Defined Atmospheric Profiles

A new enhancement to SENTRAN7 is an error checking package for the LOW-TRAN7 and MODTRAN Card 2C and Card 2D series which, respectively, contain user defined profiles of atmospheric constituents and wavelength scaling factors for aerosol attenuation. The main purpose of the package is to inform users of potentially incorrect atmospheric profiles before actually running LOWTRAN7 and MODTRAN. Thus, it serves to speed up a SENTRAN7 session because, in the previous SENTRAN7 framework, profile errors flagged by LOWTRAN7 and MOD-TRAN would become apparent only after users had run the codes and then tried plotting *TAPE7.OUT* output in the Graph and Analyze Module (unsuccessfully, of course). The error checking package writes detailed information to SENTRAN7's log file, *SEN.LOG*. The error checking package is used whenever profiles are read in and during compilation.

In the SENTRAN7 framework, the LOWTRAN7 and MODTRAN Card 2C and Card 2D series are specified in files with default extensions of *.PRO* and *.AER* extensions, respectively. These files must be created off-line by the user. Because the formats of these files mimic the LOWTRAN7 and MODTRAN card series that they represent, setting up a *.PRO* or *.AER* file from scratch involves excessive data entry and file formatting for up to 34 layers of data. Mistakes are often introduced by:

1. Mistyping numbers

2. Improper conversion from one physical unit to another

3. Incorrect physical unit specification in the JCHAR array.

Additionally, users often "tweak" their atmospheric profiles during SENTRAN7 sensitivity studies, and they may unknowingly create physically unrealistic situations, such as layers with humidities exceeding 100%. Clearly then, an error checking package is a desirable feature for SENTRAN7.

2.5.1 Types of Errors To Be Identified

Currently, the SENTRAN7 error checking package identifies two types of pitfalls:

1. Physically unrealistic layers

2. Probable trouble spots for "typical" atmospheric conditions.

Checking for physically unrealistic layers refers to things such as negative pressures and altitudes that do not increase monotonically. In the SENTRAN7 framework, these types of errors are termed Major errors. Although SENTRAN7 will permit users to continue their session, users should inspect the *SEN.LOG* file and fix the problem, because LOWTRAN7 and MODTRAN will most likely not execute successfully. Checking for probable trouble spots helps to identify more subtle problems, such as a temperature of 50 K at an altitude of 2 km. In the SENTRAN7 framework, these layers are flagged with Warnings. LOWTRAN7 and MODTRAN will probably execute when Warnings are found, but users should inspect the LOWTRAN7 and MODTRAN output because it may be erroneous.

2.5.2 Major Errors

This section gives detailed information about the Major errors to be flagged by the SENTRAN7 error checking package. A summary of the Major errors is given in Table 1 for reference. If Major errors are found, the number of Major errors are listed on the screen.

2.5.2.1 Error Checking on Altitude Profiles

In the LOWTRAN7 and MODTRAN Card 2C series, profiles are always defined along an altitude grid in km. The SENTRAN7 error checking package identifies three types of Major altitude errors including checking if:

1. Altitudes are less than 0 km
2. Altitudes exceed 100 km
3. The altitude grid does not increase monotonically.

2.5.2.2 Error Checking on Pressure Profiles

In the LOWTRAN7 and MODTRAN Card 2C series, users can specify layer pressures as a function of altitude. The SENTRAN7 error checking package identifies four types of Major pressure errors including checking for:

1. The supplied value of the units index JCHAR is not one of those allowed by LOWTRAN7 and MODTRAN for pressure
2. Pressures exceed 1100 mb
3. Pressures are negative
4. The pressure grid does not decrease monotonically.

Note that the error checking package will accept layer pressures in any of the allowed pressure units and then, for checking purposes, internally converts them to mb.

Table 1. Summary of Major Errors Flagged by the SENTRAN7 Error Checking Package. All atmospheric variables are on the LOWTRAN7 and MODTRAN Card 2C or 2D series

LOWTRAN7/MODTRAN VARIABLE	MAJOR ERROR CONDITION
Altitude	Negative value Greater than 100 km Not monotonically increasing
Pressure	Illegal value in JCHAR array Negative value Greater than 1100 mb Not monotonically decreasing
Temperature	Illegal value in JCHAR array Negative value
Water Vapor	Illegal value in JCHAR array Negative humidity Humidity greater than 100%
Other Gas Constituents	Illegal value in JCHAR array Negative ppmv Greater than 1E6 ppmv
Aerosol Vertical Scaling Factor	Negative value Greater than 100 km^{-1}
Equivalent Water Content	Negative value
Rain Rate	Negative value
Aerosol Control Variables	Bad combinations of IHA1, ICLD1, and IVUL1 IHA1 negative or greater than 10 ICLD1 negative or greater than 11 IVUL1 negative or greater than 8 ISEA1 negative or greater than 2 ICHR1 negative or greater than 1
Aerosol Extinction Coefficient	Negative value Not equal to 1 km^{-1} at 0.55 μm
Aerosol Absorption Coefficient	Negative value Greater than extinction coefficient
Aerosol Asymmetry Parameter	Less than -1.0 Greater than 1.0

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2.5.2.3 Error Checking on Temperature Profiles

In the LOWTRAN7 and MODTRAN Card 2C series, users can specify layer temperatures as a function of altitude. The SENTRAN7 error checking package imposes few limitations on temperature because users often do extreme things intentionally with temperature profiles in their sensitivity studies. Currently, two types of Major temperature profile errors are checked for:

1. The supplied value of the units index JCHAR is not one of those allowed by LOWTRAN7 and MODTRAN for temperature

2. Temperatures are negative in terms of deg K.

Note that the error checking package will accept layer temperatures in any of the allowed temperature units and then, for checking purposes, internally converts them to deg K.

2.5.2.4 Error Checking on Water Vapor Profiles

In the LOWTRAN7 and MODTRAN Card 2C series, users can specify layer concentrations of water vapor as a function of altitude. The SENTRAN7 error checking package checks for three types of Major water vapor profile errors:

1. The supplied value of the units index JCHAR is not one of those allowed by LOWTRAN7 and MODTRAN for water vapor

2. The water vapor value converts to a relative humidity value less than 0%

3. The water vapor value converts to a relative humidity value exceeding 100%.

Note that the error checking package will accept layer concentrations of water vapor in any of the allowed water vapor units and then, for checking purposes, internally converts them to relative humidity in %. Also, because the conversion to relative humidity usually involves the layer pressure and temperature, a Major error for water vapor sometimes results from erroneous values for the layer pressure and/or temperature. Currently, no checking is performed when the value of JCHAR is set to "I" which represents the use of user-defined units.

2.5.2.5 Error Checking on Other Gas Constituent Profiles

For other gas constituent profiles in the LOWTRAN7 and MODTRAN Card 2C series, the SENTRAN7 error checking package checks for three types of Major errors:

1. The supplied value of the units index JCHAR is not one of those allowed by LOWTRAN7 for major and minor gas constituents

2. The gas amount is negative

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3. The gas amount converts to a volume mixing ratio exceeding 10^6 part per million by volume.

Note that the error checking package will accept layer concentrations of gas constituents in any of the allowed gas units and then, for checking purposes, internally converts them to parts per million by volume. Currently, no checking is performed when the value of JCHAR is set to "I" which represents the use of user-defined units.

2.5.2.6 Error Checking on Aerosol Profiles

The LOWTRAN7 and MODTRAN Card 2C series allows users to specify aerosol profiles in terms of an aerosol vertical scaling factor, equivalent water content, and rain rate. The SENTRAN7 error checking package imposes almost no limitations on these atmospheric variables because users often intentionally vary them greatly in their sensitivity studies. Currently, four types of Major aerosol errors are checked for:

1. Aerosol vertical scaling factors are negative
2. Aerosol vertical scaling factors exceed 100 km^{-1}
3. Equivalent water contents are negative
4. Rain rates are negative.

Additionally, the LOWTRAN7 and MODTRAN Card 2C series allows users to specify aerosol profiles in terms of control variables. Currently, seven types of Major aerosol control variable errors are checked for:

1. Illegal combinations of IHA1, ICLD1, and IVUL1 exist (*i.e.*, only one of them should be positive)
2. IHA1, ICLD1, IVUL1, ISEA1, or ICHR1 values are negative
3. IHA1 values exceed 10
4. ICLD1 values exceed 11
5. IVUL1 values exceed 8
6. ISEA1 values exceed 2
7. ICHR1 values exceed 1.

2.5.2.7 Error Checking on Aerosol Wavelength Scaling Factors

The LOWTRAN7 and MODTRAN Card 2D series allows users to specify aerosol wavelength scaling factors in terms of normalized aerosol extinction and absorption coefficients and asymmetry parameters. For the required 47 wavelengths, the SENTRAN7 error checking package checks for seven types of Major aerosol scaling errors:

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1. Conversion factors from equivalent liquid water content to extinction coefficient are negative

2. Aerosol extinction coefficients are negative

3. Aerosol extinction coefficients do not equal 1 km^{-1} at 0.55 μm

4. Aerosol absorption coefficients are negative

5. Aerosol absorption coefficients exceed the corresponding extinction coefficients

6. Aerosol asymmetry parameters are less than -1.0

7. Aerosol asymmetry parameters are greater than 1.0.

Note that the error checking package performs these checks for each altitude region of wavelength scaling factors that have been specified by the user.

2.5.3 Warning Messages
2.5.3.1 Overview

As mentioned before, the SENTRAN7 error checking package also issues Warning messsages to inform the user of probable trouble spots in their user-defined and perturbed profiles. To do this, the SENTRAN7 error checking package compares the user-defined and perturbed profiles against the expected range of values for the atmosphere. Currently, these ranges are defined as the minimum and maximum values in the six model atmospheres (*i.e.*, *MODEL1.PRO* through *MODEL6.PRO*) plus a tolerance of 10% on the bounding values. In this scheme, the user-defined and perturbed profiles are interpolated on to the altitude grid defining the model atmospheres and the range checking is made there.

2.5.3.2 Atmospheric Variables Checked for Reasonability

Using the scheme described above, the SENTRAN7 error checking package checks layer-by-layer values of the following atmospheric variables for reasonability:

1. Pressure
2. Temperature
3. Water vapor
4. Other gas constituents.

When an atmospheric variable is between the associated minimum and maximum values for the six model atmospheres (plus a tolerance of 10% on the bounding values), SENTRAN7 defines the value as being "reasonable" and no Warning message is issued. Thus, the error checking package accepts layer-by-layer values in any of the physical units and then, for checking purposes, internally convert

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them to those used in *MODEL1.PRO* through *MODEL6.PRO*. The user should note that Warning messages are issued for water vapor in units of parts per million by volume, not humidity (as with the Major errors).

2.5.3.3 Atmospheric Variables Not Checked for Reasonability

Some atmospheric variables in the LOWTRAN7 and MODTRAN Card 2C and Card 2D series can assume a wide range of values and still be physically correct. Therefore, no Warning messages are currently issued for the following atmospheric variables:

1. Altitude
2. Aerosol vertical scaling factors
3. Equivalent water contents
4. Rain rates
5. All aerosol wavelength scaling factors.

Also, no Warning messages are issued for the aerosol control variables (*i.e.*, IHA1, ICLD1, ...) because they can only assume discrete integer values. Note that the atmospheric variables listed above are still subject to error checking for Major errors. If Warnings are found, the number of Warnings are listed on the screen.

2.6 Improved Perturbation Schemes for User-Defined Atmospheres

A new feature in SENTRAN7 is an improved scheme to perturb user-defined atmospheric profiles (*i.e.*, the Card 2C series). This feature allows users to impose perturbations in ways that are more realistic in the atmosphere. That is, the original version of SENTRAN7 only allowed users to perturb user-defined atmospheric profiles as percent perturbations such that the same perturbation amount was applied to each layer. In the real atmosphere, however, most atmospheric perturbations only occur over a localized region of the atmosphere, such as from the injection of a volcanic aerosol layer.

Two types of improved perturbations have been added to SENTRAN7:

1. Deterministic perturbations
2. Correlated and uncorrelated random perturbations.

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2.6.1 Deterministic Perturbations

The deterministic perturbation option is a simple extension of the percent perturbation feature in the original SENTRAN7 code. Now, users are able to specify a different percent perturbation for each layer in the profile of an atmospheric variable. This is a useful way to study the effects of a depleted ozone layer, for example. Currently, SENTRAN7 allows users to specify two profiles of deterministic perturbations for their sensitivity studies. This is a reasonable limit given that the SENTRAN7 Graph & Analyze package can only plot results for the first two LOWTRAN7 parameters to be perturbed. Deterministic perturbations are defined in the Define Perturbations Module and are invoked by typing 'det1' and 'det2' for an atmospheric variable in the Edit Module (see Section 4.2.3 in the Users Guide).

2.6.2 Correlated and Uncorrelated Random Perturbations

The correlated and uncorrelated random perturbation option allows users to impose different types of random perturbations on the profiles of atmospheric variables. Correlated random perturbations mean that perturbation amounts between consecutive atmospheric layers are correlated. Uncorrelated random perturbations mean that perturbation amounts for consecutive atmospheric layers are independent of each other. The governing equations for both types of random perturbations are given by Justus et al.[6]

To generate correlated and uncorrelated random perturbation profiles for an atmospheric variable, the perturbed profile, $f(z)$, is represented as a mean profile, $F(z)$, plus a random perturbation amount, $r(z)$

$$f(z) = F(z) + r(z). \tag{1}$$

For correlated random perturbations, the expression for $r(z)$ is given by

$$r(z) = \rho(\Delta z) r(z - \Delta z) + \sigma(z)\sqrt{1 - \rho^2(\Delta z)} a(z) \tag{2}$$

where $\rho(\Delta z)$ is the correlation function, $\sigma(z)$ is the standard deviation of the atmospheric variable, and $a(z)$ is a random variable with mean = 0 and variance = 1. Uncorrelated random perturbations are a limiting case of Eq. 2 where $\rho(\Delta z)$ equals zero so that Eq. 1 simplifies to

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[6] Justus, C.G., Alyea, F.N., Cunnold, D.M., Blocker, R.S., and Johnson, D.L. (1988) *Gram-88, Improvements in the Perturbation Simulations of the Global Reference Atmospheric Model*, NASA Marshall Space Flight Center, Earth Science and Applications Division, Space Science Laboratory, ES44-11-9-88.

$$f(z) = F(z) + \sigma(z)a(z). \tag{3}$$

For correlated random perturbations, the correlation function in Eq. 2 is described by the modified exponential function

$$\rho(\Delta z) = \begin{cases} 1 - A(\frac{\Delta z}{L(z)})^2, & \text{if } \frac{\Delta z}{L(z)} \leq 0.05; \\ \exp(-B\frac{\Delta z}{L(z)}), & \text{if } \frac{\Delta z}{L(z)} > 0.05; \end{cases} \tag{4}$$

where $L(z)$ is the correlation length and A and B are constants equal to 19.5162 and 1.0004, respectively. Currently, SENTRAN7 allows users to specify two profiles of correlated and uncorrelated random perturbations for their sensitivity studies. This is a reasonable limit given that the SENTRAN7 Graph & Analyze package can only plot results for the first two LOWTRAN7 and MODTRAN parameters to be perturbed. Also, at most ten random perturbation profiles can be generated for each atmospheric variable.

The basic scheme to include correlated and uncorrelated random perturbations in a SENTRAN7 sensitivity study is a two-step process. Users must first define the appropriate parameters for a random perturbation study and select a random number generation scheme in the Define Perturbations Module, and then activate the perturbations by typing 'ran1' and 'ran2' for an atmospheric variable within the Edit Module (see Section 4.2.3 in the Users Guide).

2.6.3 Perturbable Atmospheric Variables

SENTRAN7 allows users to invoke deterministic and random perturbations for most atmospheric variables in the Card 2C series. These include:

1. Pressure
2. Temperature
3. Water vapor
4. Other gas constituents
5. Aerosol vertical scaling factors
6. Equivalent water contents
7. Rain rates.

Note that SENTRAN7 allows users to enter 'det1', 'det2', 'ran1' and 'ran2' for more than one atmospheric variable in the Edit Card 2C menu, in order to impose the same deterministic or random perturbation parameters. However, the percent perturbation amounts for two atmospheric variables with the same 'ran1' or 'ran2'

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command will differ layer-by-layer because they access different portions of the random number sequence, $a(r)$.

At this point, it should be mentioned that users must exercise caution when they perturb pressure and/or temperature profiles. That is, altitude, pressure, and temperature are related by the hydrostatic relationship and, consequently, perturbing pressures while holding temperatures at their reference values (or vice versa) is not strictly correct. Therefore, it is recommended that users only specify small perturbations so departures from hydrostatic equilibrium are relatively minor.

2.7 View File Module

SENTRAN7 now contains a general View File Module in the Main Menu. Users type the name of the file to be viewed (*SEN.LOG*, for example) and the file will be scrolled on the screen. If the specifed file does not exist, then a file listing of the current directory is given. Note that View File Module converts all file names to upper case, so it cannot be used to see lower case files on Unix systems. Also, any text beyond Column 80 is not shown when the file is listed.

An example of a file being listed is shown in Figure 1. Other examples of how to use the View File Module are given in the Users Guide.

```
SENTRAN7:SUN4/UNIX Version  SPARTA, Inc.
                   SENTRAN7 VIEW FILE UTILITY



                  VIEWING FILE:  MODEL1.PRO

  33    1    1 TROPICAL
     0.000 1.013E+03 2.997E+02 2.593E+04 3.300E+02 2.869E-02AAAAAAAAAAAAAA
 3.200E-01 1.500E-01 1.700E+00 2.090E+05 3.000E-04 3.000E-04 2.300E-05 5.000E-04
           1.580E-01 0.000E+00 0.000E+00    0    0    0    0    0
     1.000 9.040E+02 2.937E+02 1.949E+04 3.300E+02 3.150E-02AAAAAAAAAAAAAA
 3.200E-01 1.450E-01 1.700E+00 2.090E+05 3.000E-04 2.740E-04 2.300E-05 5.000E-04
           9.910E-02 0.000E+00 0.000E+00    0    0    0    0    0
     2.000 8.050E+02 2.877E+02 1.534E+04 3.300E+02 3.342E-02AAAAAAAAAAAAAA
 3.200E-01 1.399E-01 1.700E+00 2.090E+05 3.000E-04 2.360E-04 2.300E-05 4.630E-04
           6.210E-02 0.000E+00 0.000E+00    0    (    0    0    0
     3.000 7.150E+02 2.837E+02 8.600E+03 3.300E+02 3.504E-02AAAAAAAAAAAAAA
 3.200E-01 1.349E-01 1.700E+00 2.090E+05 3.000E-04 1.900E-04 2.300E-05 3.800E-04
                  ...MORE... HIT <RETURN> TO CONTINUE
```

Figure 1. Example of a File Listing With SENTRAN7's View File Module

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2.8 Renaming of Output Files from LOWTRAN7 and MODTRAN

Users can now instruct SENTRAN7 to save output files from LOWTRAN7 and MODTRAN as customized file names. This feature is particularly useful because these codes overwrite the files using standard output names (*i.e.*, *TAPE7*) each time the Run Module is selected within SENTRAN7. Specifically, SENTRAN7 creates customized file names by first identifying the root name of the *.INP* file and then appending the following extensions:

1. *TAPE6* output is copied to *root name.TP6*
2. *TAPE7* output is copied to *root name.TP7*
3. *TAPE8* output is copied to *root name.TP8*

If the input file generated by SENTRAN7 for LOWTRAN7 and MODTRAN is named *SPACE.INP*, for example, then the output in *TAPE6*, *TAPE7*, and *TAPE8* output is copied to *SPACE.TP6*, *SPACE.TP7*, and *SPACE.TP8*, respectively. This feature is exercised from the Run Module (see the Users Guide).

2.9 Optional Display of Absorbing Species

SENTRAN7 now permits users to deactivate the listing of active molecular absorbers in the Compile Module. To do this, users type 'abs' from the Main Menu (see the ABS command in the Users Guide for details). This feature has been added to SENTRAN7 to speed up sensitivity studies that involve wavelength regions with many molecular absorption bands. That is, the process of listing all molecular absorbers can be time consuming, requiring users to hit RETURN many times.

2.10 Improved Method of Perturbation for Card 2C3 Parameters

SENTRAN7 now contains an improved algorithm to perturb the IHA1, ICLD1, IVUL1, ISEA1, and ICHR1 parameters on CARD 2C3. Previously, the menu in the Edit Module would only accept percent perturbations for these parameters when, in fact, they are supposed to be set to discrete integer values. Given that the percent perturbations must be less than 100%, any sensitivity study involving the IHA1, ICLD1, IVUL1, ISEA1, and ICHR1 parameters would always be assigned the default values in the *.PRO* file. The Edit Module now accepts integer perturbation values for the IHA1, ICLD1, IVUL1, ISEA1, and ICHR1 parameters (see Section 4.2.3.5).

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3 INSTALLING AND RUNNING SENTRAN7

3.1 Overview of Software

SENTRAN7 is designed to be highly portable, while maintaining a reasonably high level of performance. These goals dictate the use of highly portable code and common standards for graphics and terminal control. Given these requirements, SENTRAN7 is coded in Fortran-77. The code utilizes the Tektronix 4010/4014 format standards for graphics[7] and the American National Standards Institute (ANSI) standard for terminal control.[8] Tektronix 4010/4014 is selected because it is probably the most popular graphics format to be emulated. Moreover, graphics and terminal control kernels in SENTRAN7 are completely self contained, obviating the need for external software libraries. Digital Equipment Corporation's VT240 terminal (along with several VT240 compatibles available from other manufacturers) supports both the ANSI and TEK4010 standards, so it is an ideal terminal for interactive viewing of SENTRAN7 graphics. It is noted that the VT240 is, in fact, one of the industry standard graphics terminals which endorses SENTRAN7's choice of standards.

3.2 Installing the Program

Table 2 lists the files included with the SENTRAN7 package. To install the code, first create a subdirectory to contain the programs and data files. Once this has been completed, copy the files from the distribution media into the target subdirectory.

SENTRAN7 can be compiled to run on either a VAX/VMS^{TM} system or Sun Microsystems^{TM} computer. The following instructions explain how to compile and link SENTRAN7:

- For a VAX/VMS^{TM} system, type '@makefile'. This creates the executable file *sentran.exe*.

- For a Sun^{TM} computer, type 'make'. This creates the executable file *sentran*. Note that some Sun^{TM} computers will generate a series of warning messages during compilation which can be ignored by the user.

To start the program, the user simply types 'r sentran' if on a VAX/VMS^{TM} system.

On a Sun^{TM} computer, SENTRAN7 should be executed from the *xterm* Tektronix 4014 terminal emulator program, which is part of the X Window System

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[7] Tektronix, Inc. (1977) *Users Guide and Service Manual for 4014, 4014-1 Terminals*, Tek Part No. 070-1647-00, Beaverton, OR.

[8] ANSI Standard X3.64 (1979) *Additional Controls for Use With ASCII*, Secretariat: CBEMA, 1828 L St., N.W., Washington, DC.

Table 2. Files Included with the SENTRAN7 Package. File listing is for UNIX systems. Users must change "*.f" extensions to "*.for" for VAX/VMS™ systems

FILE NAME	CONTENTS
senmain.f	Source code for SENTRAN7 (main program only)
sensubs.f	Source code for SENTRAN7 (supporting routines)
senpert.f	Source code for SENTRAN7 (perturbation routines)
senchk.f	Source code for SENTRAN7 (error checking routines)
senvms.for	Source code for SENTRAN7 (VAX computer systems only)
senunix.f	Source code for SENTRAN7 (UNIX computer systems only)
andor.c	Fortran bit manipulation code (UNIX computer systems only)
MAJABS.DAT	Data file defining regions of molecular absorption
DIRECT.ORY	Configuration file containing directory and name of LOWTRAN7 and MODTRAN executables and the *UFTAPE.DAT* file. Current directory is assumed when *DIRECT.ORY* does not exist
SENTRAN.HLP	SENTRAN7 on-line help utility file
MODEL1.PRO	Tropical atmosphere profile (*i.e.*, Card 2C series)
MODEL2.PRO	Midlatitude summer profile
MODEL3.PRO	Midlatitude winter profile
MODEL4.PRO	Subarctic summer profile
MODEL5.PRO	Subarctic winter profile
MODEL6.PRO	U.S. standard profile
SAMPLE.AER	Sample Card 2D series: normalized aerosol extinction versus wavelength for four aerosol regions
SAMPLE.PHS	Sample Card 3B series: aerosol phase functions for four aerosol regions
SAMPLE.RND	Sample random perturbations input file
DEFAULT.MTH	Sample methodology file (used in Tutorial #1)
lowtran7.f	Source code for LOWTRAN7
modtran.f	Source code for MODTRAN
mkbin.f	Program creates *UFTAPE.DAT* from *BMTAPE.DAT*
makefile.com	Command file for compiling and linking SENTRAN7 on VAX/VMS systems. Type '@makefile' to execute
makefile	Unix command file for compiling and linking SENTRAN7 on SUN systems. Type 'make' to execute

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OpenWindows. To do this, make sure the current path includes the *xterm* terminal emulator program and type 'openwin' to enter OpenWindows. To execute SENTRAN7, type 'xterm -geometry 80x24 -e sentran'. An *xterm* window will appear and SENTRAN7 will automatically begin execution. Under *xterm*, the scrolling features in SENTRAN7 work properly and the user can easily view SENTRAN7 Tektronix plots (see Section 4.2.8.6 for details).

3.3 LOWTRAN7 and MODTRAN Requirements

Source codes for both LOWTRAN7 and MODTRAN are included with SENTRAN7. Slight modifications have been made to both source codes in order to run with SENTRAN7. The user is referred to Appendix B for a discussion of the changes. Other than the modifications specified here, no other modifications to either LOWTRAN7 or MODTRAN are allowed if they are to work with SENTRAN7.

LOWTRAN7 has been modified to continue layer-by-layer calculations even when the differential transmittance (DTAU) has become very small. In the standard version of LOWTRAN7, the program would jump out of the calculation loop when DTAU was less than 10^{-5}. For SENTRAN7 however, the complete array of DTAU and flux data must be included in *tape8* to avoid empty regions or "gaps" in the 3D plots of DTAU and flux data. For reference, these code changes are given in Appendix B. The code changes to LOWTRAN7 are included with this distribution. It is worth noting that coding changes for Version 4.2 of LOWTRAN7 (released 2 February 1992) address this DTAU issue. Thus, users who receive updates and errata for LOWTRAN7 may have made the DTAU code changes already. Note that, the changes made to LOWTRAN7 are recommended changes, but are not required to run LOWTRAN7 with SENTRAN7.

MODTRAN has been similarly modified in order to continue layer-by-layer calculations even when DTAU has become very small. In addition, because the input structure for MODTRAN is slightly different from LOWTRAN7, MODTRAN must be modified slightly to work with SENTRAN7. For reference, these code changes are also given in Appendix B. The modified version of MODTRAN is included as part of the SENTRAN7 package (*modtran.f*). Note that the changes made to MODTRAN are required in order for MODTRAN to work with SENTRAN7.

3.4 Using the *DIRECT.ORY* File

The *DIRECT.ORY* file allows users to specify the directory where the executable codes for LOWTRAN7 and MODTRAN reside. A sample *DIRECT.ORY* file has been included with the SENTRAN7 package. SENTRAN7 uses this file to locate the executable code for the transmission model chosen by the user. The

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file, *DIRECT.ORY*, should be edited with a standard text editor on the user's computer system to indicate the directories and names of the executable codes for LOWTRAN7 and MODTRAN, as well as the location of MODTRAN's molecular absorption data file called *UFTAPE.DAT*. Note that, if *DIRECT.ORY* does not exist, SENTRAN7 searches the current directory for the appropriate files.

4   USERS GUIDE FOR SENTRAN7

This users guide is targeted at both novice and experienced SENTRAN7 users, and provides an overview of SENTRAN7's structure and usage. Details of command usage in a quick reference format, may be found in Appendix C. Recall that SENTRAN7 can execute either LOWTRAN7 or MODTRAN. Unless explicitly stated, the use of the term MODTRAN will imply reference to both LOWTRAN7 and MODTRAN.

4.1   Overview of SENTRAN7

A brief overview of SENTRAN7 is given in this section for users who are not familiar with the original SENTRAN code. Users who are familiar with the features of the original SENTRAN may skip this section and proceed to Section 4.2.

4.1.1   Code Philosophy

SENTRAN7 is a general purpose computer code that facilitates the analysis of MODTRAN's response to the perturbation of its input parameters. SENTRAN7 is primarily designed as a comfortable, interactive interface to MODTRAN with special provisions for perturbation analysis. Using SENTRAN7, one can easily extract, analyze, reduce, and plot MODTRAN output. These features permit users to rapidly perform analyses that would be difficult or impossible through brute-force techniques. The process is highly automated and requires little effort on the part of the user because SENTRAN7 is "intelligent" enough to keep track of the details of parameter variation. Also, SENTRAN7 contains many useful analysis tools such as evaluating partial derivatives of a variable represented by the z axis with respect to two independent variables given by the x and y axes. Using these capabilities, users can rapidly determine those regions where MODTRAN's calculations are most sensitive.

SENTRAN7 makes extensive use of graphics to display results. The human eye possesses strong abilities with respect to trend analysis and can identify complicated patterns at a glance. These capabilities are fully exploited in SENTRAN7 via the use of 3D surface plots, enabling users to visualize MODTRAN's response to the simultaneous variation of two parameters. These plots can be archived as files for hard-copy generation and/or later perusal on a graphics terminal.

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4.1.2 Design Criteria

The design of SENTRAN7 was based on the following general criteria:

1. User friendliness
2. Framework for sensitivity analyses
3. High portability
4. Quick turnaround time for interactive analyses
5. Extensive use of graphics for data presentation
6. Provisions for data analysis and reduction tools.

User friendliness is one of the single greatest considerations in SENTRAN7's design. Most of SENTRAN7 is devoted to providing users with a comfortable working environment, without compromising flexibility or power. User friendliness is implemented in a number of ways, including:

1. The code is virtually crash proof, using character oriented input for command strings and numerical values. Before being accepted, numerical inputs are examined to make sure they are physically meaningful.
2. Commands can be entered in upper, lower, or mixed case.
3. Abundant feedback is provided, including step-by-step prompts and ample information when the code cannot properly read user-specified input files.
4. The command interpreter can resolve the component parts of complicated input strings, bypassing input prompts, thus permitting veteran users to use the code with increased speed.
5. Sensible defaults are provided wherever possible, reducing the chance of erroneous input.
6. On-line help is available, minimizing the amount of time required to learn how to use SENTRAN7. The help feature also provides information on MODTRAN inputs.

While this list is by no means complete, it provides an idea of the user friendly features of SENTRAN7. Collectively, these features eliminate the need to concentrate on file and data manipulation so users can focus on the scientific aspects of their MODTRAN analysis problems.

Another important requirement is the ease and speed of post-processing of MODTRAN outputs. SENTRAN7 tries to isolate MODTRAN from the user as much as possible so that the user need not be aggravated by bookkeeping. It can extract transmittance and/or radiance data from MODTRAN's *tape7* and *tape8* output files. Also, SENTRAN7 is intelligent enough to prompt the user with the

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list of input parameters that can be chosen as independent variables for plotting and derivative computation.

Data analysis and reduction tools are provided along with graphics in an interactive module. The analysis tools include common data manipulations such as logarithmic transformation of data and partial derivatives of first and second order with respect to the independent axes. Furthermore, SENTRAN7 can read and plot raw data files as well as output the reduced data as raw data files for use in commercial plotting packages.

4.2 Program Structure

SENTRAN7 is structured into a number of subprograms called modules. Each module performs a specific task to aid users in their sensitivity studies. The modules are ordered according to the way users would typically conduct a sensitivity study. The seven main modules of SENTRAN7 are listed in Table 3. The SENTRAN7 Main Menu is shown in Figure 2. The following sections provide specific details on how to use each of the SENTRAN7 modules.

4.2.1 Help Module

On-line help is available at almost all locations within the SENTRAN7 program. Specifically, help information is available at the Main Menu, within the Edit Module, and within the Graph & Analyze Module of SENTRAN7. At the Main Menu, users can obtain general information about most of SENTRAN7's modules listed in Table 3. To access this information, the user enters the command 'help' followed by a module name from the Main Menu Screen. For example, the user could enter 'help load' for a description of the LOAD command. In the absence of a module name, an introductory help screen appears which displays a list of help topics (see Figure 3). Users can then enter the name of a selected topic, whereupon they will receive help on that particular topic. If the user does not select a topic, or selects an invalid topic, control will return to the Main Menu. On-line help is also available in the Edit Module and the Graph and Analyze Module of SENTRAN7. These on-line help capabilities are described in greater detail in Sections 4.2.4.6 and 4.2.8.5, respectively.

4.2.2 Load/Save Module

In SENTRAN7, images of MODTRAN input parameters and commands for their perturbation are contained in files known as "methodology" files. These files are stored on the host computer with *MTH* extensions. Methodology files enable users to store various methodologies and use them as starting points for new calculations. A more detailed description of a methodology file is given in Appendix A.

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Table 3. List of SENTRAN7 Modules

MODULE	MAIN FUNCTION
Help	Provides help for SENTRAN7 users
Load/Save	Loads and saves SENTRAN7 methodology files
Define Perturbations	Defines deterministic and random perturbation parameters for atmospheric variables in the Card 2C series
Edit	Permits users to define their MODTRAN problems, including atmospheric inputs and commands for their perturbation
Compile	Creates MODTRAN input file based on editing session and displays major molecular absorbers
Select	Selects code to be used: LOWTRAN7, MODTRAN or MODTRAN run as LOWTRAN7
Run	Executes selected code, and creates MODTRAN's *tape7* and *tape8* files
Graph and Analyze	Extracts output data, analyzes and graphs, and reduces data I/O
View File	Views files without exiting SENTRAN7

```
SENTRAN7 : SUN4/UNIX Version    SPARTA, Inc.

LOG ON                   WELCOME TO SENTRAN7
         THE SENSITIVITY ANALYSIS PROGRAM FOR LOWTRAN7/MODTRAN

                    1 - LOAD/SAVE

                    2 - DEFINE PERTURBATIONS

                    3 - EDIT

                    4 - COMPILE

                    5 - SELECT LOWTRAN7/MODTRAN

                    6 - RUN MODTRAN

                    7 - GRAPH & ANALYZE

                    8 - HELP

                    9 - VIEW FILE

                   10 - QUIT
?
```

Figure 2. Display of the SENTRAN7 Version 2.0 Main Menu

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```
┌─────────────────────────────────────────────────────────────┐
│ [U]              SENTRAN7 : SUN4/UNIX Version   SPARTA, Inc.  │
│                SENTRAN7 ONLINE HELP UTILITY                    │
│                                                               │
│         HELP IS AVAILABLE ON THE FOLLOWING TOPICS :           │
│                                                               │
│         LOAD     SAVE     DEFINE    EDIT     COMPILE           │
│                                                               │
│         SELECT   RUN      GRAPH     ANALYZE                    │
│                                                               │
│         VIEW     SEARCH   ZAP       LOG      ABS               │
│                                                               │
│                                                               │
│       ENTER THE NAME OF THE SUBJECT FOR WHICH YOU NEED HELP    │
│          OR PRESS <RETURN> TO RETURN TO MAIN PROGRAM          │
│                                                               │
│       NOTE:     THE HELP COMMAND ACCEPTS THE ABOVE ITEMS AS   │
│                    ARGUMENTS, BYPASSING THIS SCREEN           │
│                    EXAMPLE: HELP EDIT                         │
│                                                               │
│  HELP █                                                       │
│                                                               │
│                                                               │
│                                                               │
└─────────────────────────────────────────────────────────────┘
```

Figure 3. The Introductory Help Screen in the Help Module

The Load/Save Module is where users load and save selected methodology files. To load a methodology file, the user enters '1' or 'load' at the Main Menu prompt. If the user enters '1', SENTRAN7 will ask the user whether they want to load or save a methodology file. The user then enters 'load' or simply 'l', in order to load a file. The program will then display a list of all files with a *MTH* extension present in the current directory and will prompt the user for the file name to load. If the user knows which methodology file they wish to load at the Main Menu, several steps can be saved by simply entering 'load *filename*' at the Main Menu prompt, where *filename* is the name of the methodology file to be loaded. Recall that a *MTH* extension is presumed on methodology files unless the user specifies a different extension. For example, typing 'load example' will load a file named *EXAMPLE.MTH*, while typing 'load wierd.ext' will load a file named *WIERD.EXT*.

Similarly, if the user wishes to save the current values of all the parameters set within the Edit Module, to a methodology file, the user enters '1' or 'save' at the Main Menu prompt. If the user enters '1', they must then choose the save option. The user is then prompted for the name of the methodology file to save the current parameter values in. This file is also given a *MTH* default extension unless a different extension is specified by the user. If the file already exists, the user must confirm that the file is to be overwritten. If the user enters 'n', program control will be returned to the Main Menu and the methodology file will not be overwritten. Saving methodology files allows the user to easily restore the parameters used for

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a given simulation.

It is worth noting that the current values of the parameters set within the Edit Module are saved to a special file, *LAST.MTH*, after every completed editing session (*i.e.*, an editing session in which the user does not proceed to the Main Menu via the END command) and after every compilation. This file is loaded into SENTRAN7 at the beginning of the next SENTRAN7 session and provides a default methodology for the session. Therefore, users are cautioned against saving methodology files named *LAST.MTH*, or tampering with the *LAST.MTH* file in any way.

4.2.3 Define Perturbations Module

The Define Perturbations Module is a new feature in SENTRAN7 in which users can specify deterministic and random pertubation parameters for their sensitivity studies. The parameters in this module apply to sensitivity studies with user-defined atmospheric profiles (*i.e.*, the Card 2C series). Thus, users must have defined a LOWTRAN7 or MODTRAN problem with MODEL=7 on Card 1. Specifically, users can impose deterministic and random perturbations on layer-by-layer values of:

1. Pressure
2. Temperature
3. Water vapor
4. Other gas constituents
5. Aerosol vertical scaling factors
6. Equivalent water contents
7. Rain rates.

Within the SENTRAN7 framework, user-defined atmospheric profiles are stored in files that must be created off-line by the user. The default extension of these files is *PRO*.

To select the Define Perturbations Module, the user simply types '2' or 'define' at the Main Menu command line. The Define Perturbations submenu then appears, as shown in Figure 4.

4.2.3.1 Overview

The basic scheme to include deterministic and random perturbations in a SEN-TRAN7 sensitivity study is a two-step process. Users must first define the appropriate parameters for a deterministic or random perturbation study in the Define Perturbations Module and then activate these perturbations for an atmospheric variable within the Edit Module. Additionally, users must select a random number

```
  SENTRAN7 : SUN4/UNIX Version            SPARTA, Inc.
                   SENTRAN7 EDITING UTILITY


       TWO TYPES OF PERTURBATIONS ARE AVAILABLE IN SENTRAN7.
       INVOKE THESE PERTURBATIONS FOR CARD 2C PARAMETERS
       IN THE EDIT MODULE BY TYPING RAN1, RAN2, DET1, DET2.



           SELECT THE TYPE OF PERTURBATION:

           1 - RANDOM PERTURBATIONS

           2 - DETERMINISTIC PERTURBATIONS

           3 - EXIT TO MAIN MENU

           ?
```
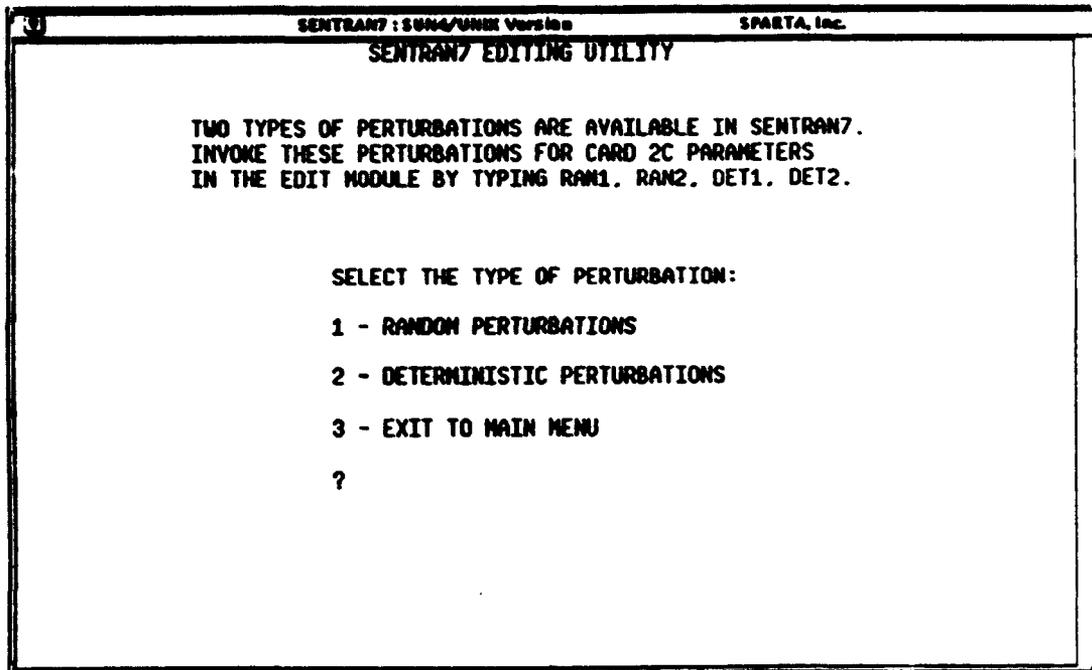
Figure 4. Display of the Define Perturbations Submenu

generation scheme when the random perturbation option is used. In the subsections to follow, the scheme to specify and activate deterministic and random perturbations is described, although the full procedure involves user actions in the Define Perturbations Module and the Edit Module.

4.2.3.2 Define Deterministic Perturbations Option

To define deterministic perturbations, type '2' at the Define Perturbations submenu, as shown in Figure 5. The menu to define the first set of deterministic perturbations then appears, as shown in Figure 6. Here, users can then enter percent perturbations for the layers of their choosing. To move around in this menu, users can use the cursor control commands from the Edit Module. (See Section 4.2.4.2 and Table 6 for a detailed description of the cursor control commands. Also, recall that all cursor control commands and percent perturbations must be followed by a RETURN.) For example, if users want to perturb the 6th layer by 10%, this can be achieved by entering 'dn 5' and then '%10'. Note that layers with no percent perturbations will not be perturbed. After specifying percent perturbations by layer, users can type 'pd' which causes users to confirm their inputs, as shown in Figure 7. If 'y' is entered, SENTRAN7 displays the menu to define the second set of deterministic perturbations. Here, users can enter additional layer-by-layer percent perturbations, if desired. Note that the user does not have to use both sets of deterministic perturbations. To return to the Main Menu, type 'end'.

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```
┌──────────────────────────────────────────────────────────────┐
│ ⊡          SENTRAN7 : SUN4/UNIX Version          SPARTA, Inc.  │
│ ┌────────────────────────────────────────────────────────────┐│
│ │              SENTRAN7 EDITING UTILITY                       ││
│ │                                                            ││
│ │                                                            ││
│ │   TWO TYPES OF PERTURBATIONS ARE AVAILABLE IN SENTRAN7.     ││
│ │   INVOKE THESE PERTURBATIONS FOR CARD 2C PARAMETERS         ││
│ │   IN THE EDIT MODULE BY TYPING RAN1, RAN2, DET1, DET2.      ││
│ │                                                            ││
│ │                                                            ││
│ │      SELECT THE TYPE OF PERTURBATION:                       ││
│ │                                                            ││
│ │      1 - RANDOM PERTURBATIONS                               ││
│ │                                                            ││
│ │      2 - DETERMINISTIC PERTURBATIONS                        ││
│ │                                                            ││
│ │      3 - EXIT TO MAIN MENU                                  ││
│ │                                                            ││
│ │      ?2▮                                                    ││
│ │                                                            ││
│ │                                                            ││
│ │                         .                                  ││
│ └────────────────────────────────────────────────────────────┘│
└──────────────────────────────────────────────────────────────┘
```
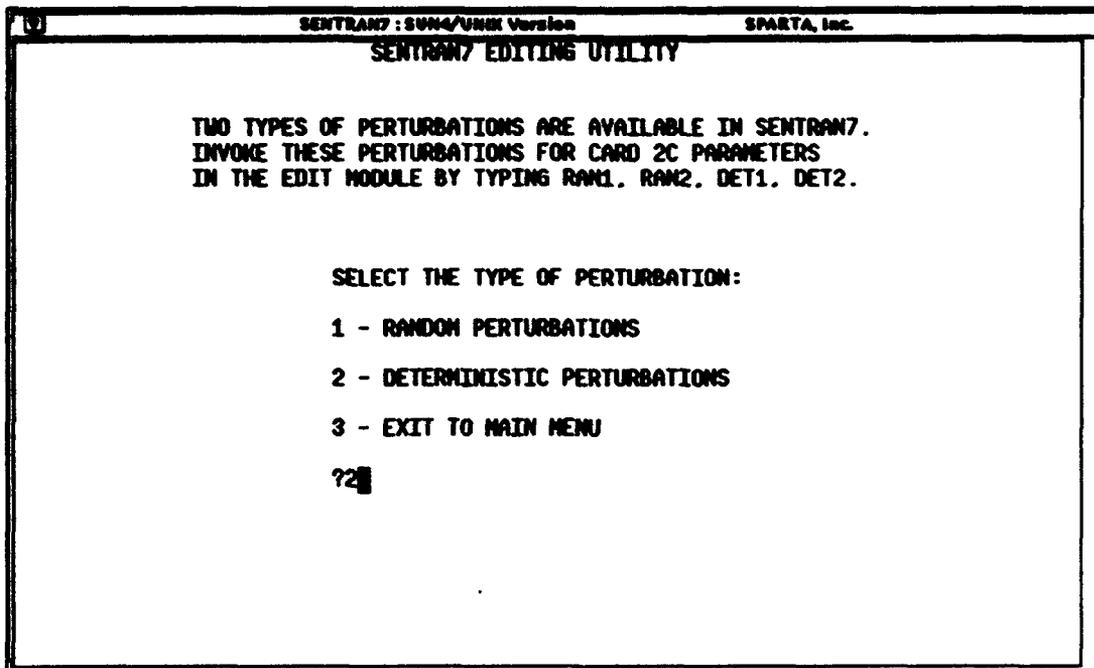
Figure 5. Example of the Command Used to Define Deterministic Perturbations

```
┌──────────────────────────────────────────────────────────────┐
│ ⊡          SENTRAN7 : SUN4/UNIX Version          SPARTA, Inc.  │
│ ┌────────────────────────────────────────────────────────────┐│
│ │              SENTRAN7 EDITING UTILITY                       ││
│ │         DEFINE FIRST DETERMINISTIC PERTURBATION             ││
│ │                                                            ││
│ │         ENTER % PERTURBATION FOR ANY LAYER(S)              ││
│ │                                                            ││
│ │  LAYER  % AMT        LAYER  % AMT        LAYER  % AMT      ││
│ │    1    ▮             13                  24                ││
│ │    2                  14                  25                ││
│ │    3                  15                  26                ││
│ │    4                  16                  27                ││
│ │    5                  17                  28                ││
│ │    6                  18                  29                ││
│ │    7                  19                  30                ││
│ │    8                  20                  31                ││
│ │    9                  21                  32                ││
│ │   10                  22                  33                ││
│ │   11                  23                  34                ││
│ │   12                                                       ││
│ │                                                            ││
│ │                                                            ││
│ │                                              .             ││
│ └────────────────────────────────────────────────────────────┘│
└──────────────────────────────────────────────────────────────┘
```
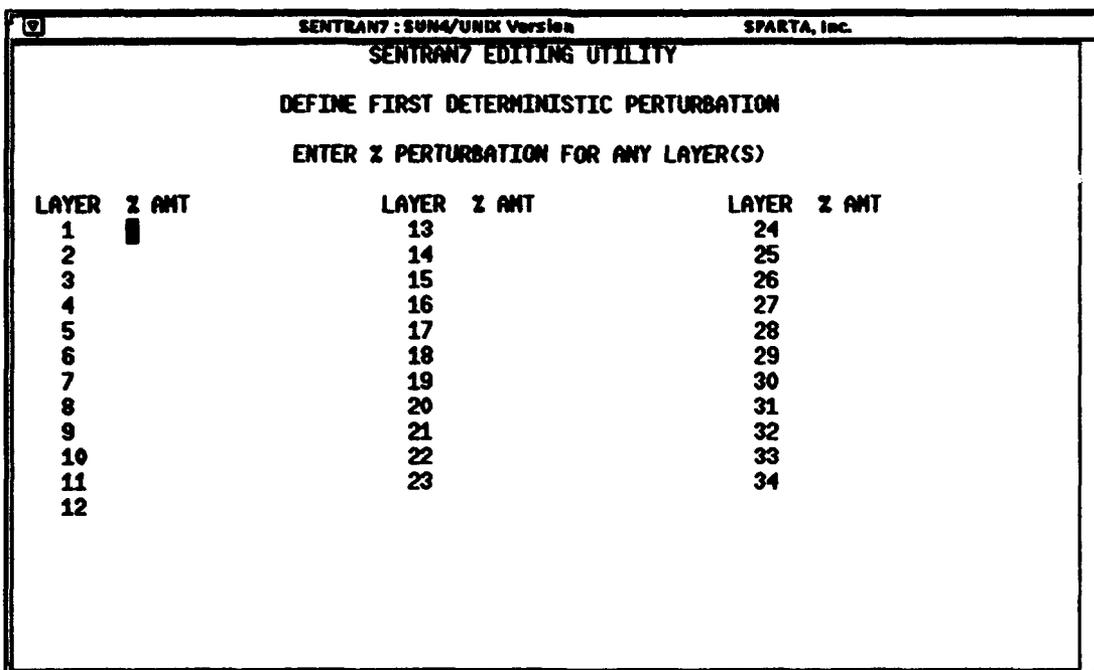
Figure 6. Menu to Define the First Set of Deterministic Perturbations. A similar menu is available for the second set of deterministic perturbations

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4.2.3.3 Define Random Perturbations Option

To define random perturbations, type '1' at the Define Perturbations submenu, as shown in Figure 8. The menu to define random perturbations then appears, as shown in Figure 9. Note that the menu contains parameters to generate two random perturbation profiles. The meaning of these parameters and their allowable values are given in Table 4. To move around in this menu, users can use the cursor control commands from the Edit Module. (Recall that all cursor control commands and numerical inputs must be followed by a RETURN.)

In Table 4, the parameters NPERT1 and NPERT2 tell SENTRAN7 how many randomly perturbed profiles to generate. Currently, the first randomly perturbed profile is set to the mean profile because SENTRAN7 must retain it for use as the nominal profile. If NPERT1=5, for example, SENTRAN7 will generate five profiles, but the first profile is the mean profile. Note that if a sensitivity problem is compiled with the NOMESH option, the LOWTRAN7 and MODTRAN run with the mean profile is placed last in the perturbation sequence which is consistent with the original programming structure of SENTRAN.

In Table 4, the parameters RFLG1 and RFLG2 determine the source of the standard deviation and correlation length data (i.e., $\sigma(z)$ and $L(z)$). For clarity on this issue, SENTRAN7 only allows users to specify SIGMA1 and L1 when RFLG1=0. Similarly, SENTRAN7 only allows users to specify files of $\sigma_f(z)$ and $L(z)$ when RFLG1=7. The default extension for these files is .RND and the file format is given in Appendix A. Also, it is worth mentioning that the random perturbation menu is used to specify both correlated and uncorrelated random perturbation types. To simulate uncorrelated perturbations when RFLG1=0, users must set L1 equal to zero. To simulate uncorrelated perturbations when RFLG1=7, users must set the values of $L(z)$ in the .RND file equal to zero.

After specifying the parameters to generate random perturbation profiles, users should enter 'pd' which causes users to confirm their inputs, as shown in Figure 10. If 'y' is entered, then SENTRAN7 will prompt users for random number information which is discussed in the next section.

4.2.3.4 Select a Random Number Generator for Random Perturbations

The random perturbation technique used by SENTRAN7 requires the generation of a random variable with a mean = 0 and variance = 1. Currently, the SENTRAN7 uses the random number generator from the Numerical Recipes Library[9]. This set of routines makes use of an integer seed that serves the following purposes:

---

[9] Press, W.H., Flannery, B.P., Teukolsky, S.A. and Vetterling, W.T. (1986) *Numerical Recipes*, Cambridge University Press, New York, NY.

```
SENTRAN7 : SUN4/UNIX Version                    SPARTA, Inc.
                    SENTRAN7 EDITING UTILITY

                DEFINE FIRST DETERMINISTIC PERTURBATION

                ENTER % PERTURBATION FOR ANY LAYER(S)

    LAYER  % AMT              LAYER  % AMT              LAYER  % AMT
      1                         13                        24
      2                         14                        25
      3                         15                        26
      4                         16                        27
      5                         17                        28
      6     %10                 18                        29
      7                         19                        30
      8                         20                        31
      9                         21                        32
     10                         22                        33
     11                         23                        34
     12

    FIRST DETERMINISTIC PERTURBATION O.K. (Y/N) [Y]
```
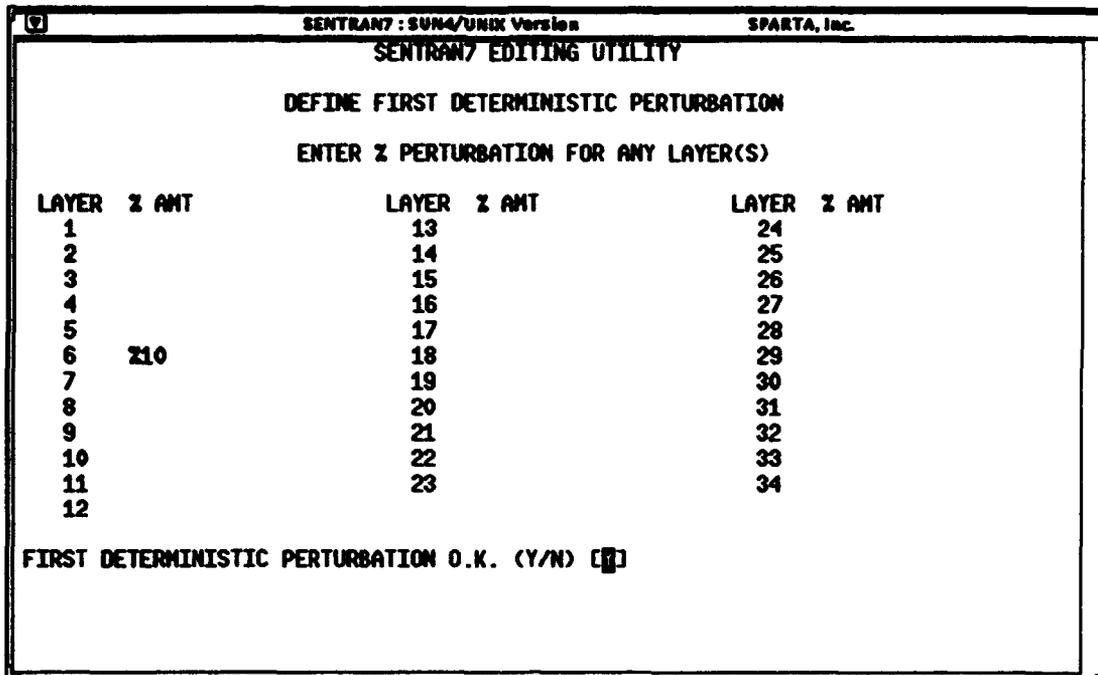
Figure 7. Example of the Final Screen Displayed After Defining the First Set of Deterministic Perturbations. In this example, the user opted to perturb the 6th layer by 10%

```
SENTRAN7 : SUN4/UNIX Version                    SPARTA, Inc.
                    SENTRAN7 EDITING UTILITY


        TWO TYPES OF PERTURBATIONS ARE AVAILABLE IN SENTRAN7.
        INVOKE THESE PERTURBATIONS FOR CARD 2C PARAMETERS
        IN THE EDIT MODULE BY TYPING RAN1, RAN2, DET1, DET2.



            SELECT THE TYPE OF PERTURBATION:

            1 - RANDOM PERTURBATIONS

            2 - DETERMINISTIC PERTURBATIONS

            3 - EXIT TO MAIN MENU

            ?1
```
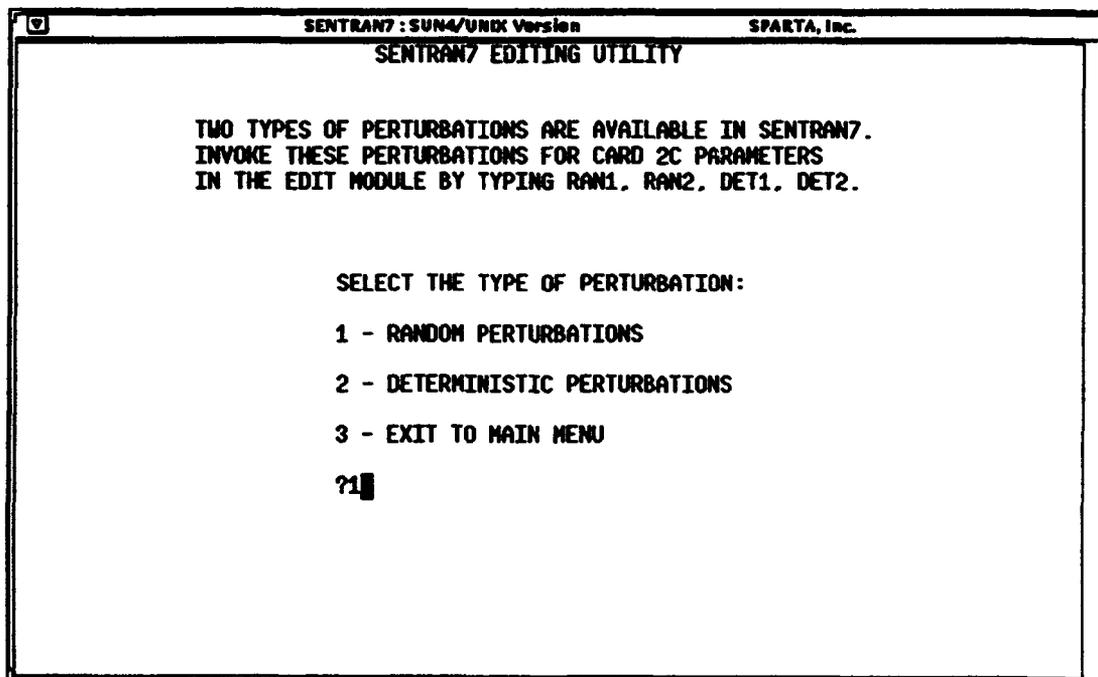
Figure 8. Example of the Command Used to Define Random Perturbations

```
 [U]              SENTRAN7 : SUN4/UNIX Version              SPARTA, Inc.
                       SENTRAN7 EDITING UTILITY

                   DEFINE RANDOM PERTURBATION PARAMETERS

                       ALL PARAMETERS TAKE ONE VALUE

 FIRST RANDOM PERTURBATION:
 NPERT1  █          2
 RFLG1              0
 SIGMA1             25
 RHO1        10.000
 FILENAME FOR SIGMA1 AND RHO1 PROFILE [.RND]

 SECOND RANDOM PERTURBATION (OPTIONAL):
 NPERT2             0
 RFLG2              0
 SIGMA2
 RHO2         0.000
 FILENAME FOR SIGMA2 AND RHO2 PROFILE [.RND]
```
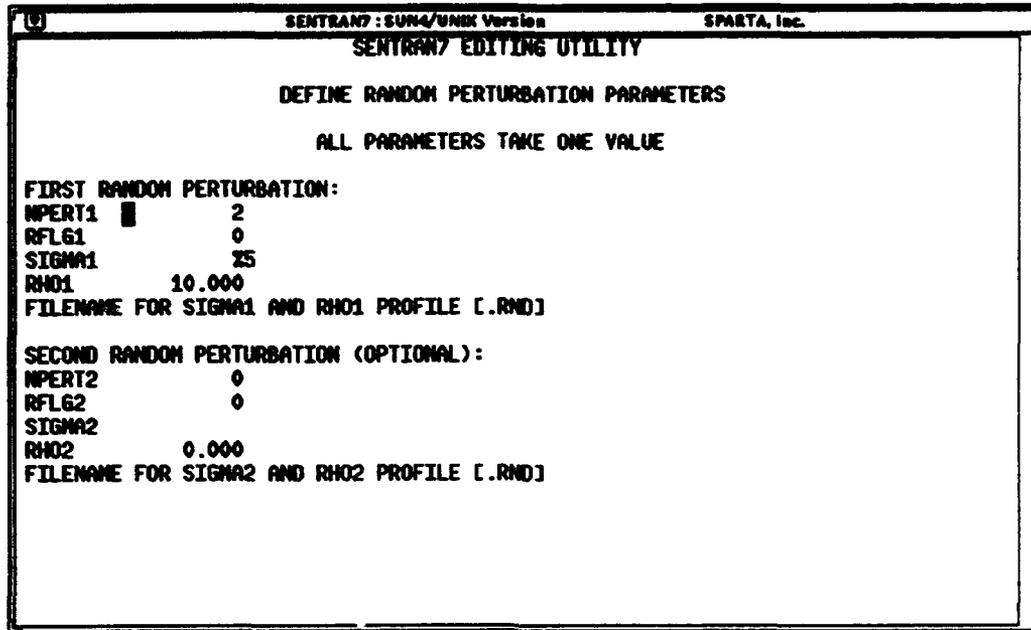
Figure 9. Menu Displayed to Define Correlated and Uncorrelated Random Perturbations

Table 4. Summary of Parameters Used to Define Random Perturbations

RANDOM PERTURBATION PARAMETER	POSSIBLE VALUES	MEANING
	FIRST	RANDOM PERTURBATION
NPERT1	1-10	Number of random profiles to generate
RFLG1	0 or 7	Source of correlation length and standard deviation data
SIGMA1	> 0*	Height independent standard deviation (used if RFLG1=0)
L1	≥ 0	Height independent correlation length (used if RFLG1=0)
Filename	-	File of layer-by-layer standard deviations and correlation lengths (used if RFLG1=7)
	SECOND	RANDOM PERTURBATION
NPERT2	1-10	Number of random profiles to generate
RFLG2	0 or 7	Source of correlation length and standard deviation data
SIGMA2	> 0*	Height independent standard deviation (used if RFLG2=0)
L2	≥ 0	Height independent correlation length (used if RFLG2=0)
Filename	-	File of layer-by-layer standard deviations and correlation lengths (used if RFLG2=7)

* Expressed as a percentage (*i.e.*, "%10") or an absolute magnitude (*i.e.*, "123.456")

```
┌─────────────────────────────────────────────────────────────┐
│ ⊡        SENTRAN7 : SUN4/UNIX Version          SPARTA, Inc.   │
│                  SENTRAN7 EDITING UTILITY                     │
│                                                              │
│              DEFINE RANDOM PERTURBATION PARAMETERS           │
│                                                              │
│                 ALL PARAMETERS TAKE ONE VALUE               │
│                                                              │
│  FIRST RANDOM PERTURBATION:                                  │
│  NPERT1            2                                         │
│  RFLG1             0                                         │
│  SIGMA1           25                                         │
│  RHO1         10.000                                         │
│  FILENAME FOR SIGMA1 AND RHO1 PROFILE [.RND]                │
│                                                              │
│  SECOND RANDOM PERTURBATION (OPTIONAL):                     │
│  NPERT2            0                                         │
│  RFLG2             0                                         │
│  SIGMA2                                                      │
│  RHO2          0.000                                         │
│  FILENAME FOR SIGMA2 AND RHO2 PROFILE [.RND]               │
│                                                              │
│                                                              │
│  ALL PARAMETERS O.K. (Y/N) [█]                              │
│                                                              │
│                                                              │
└─────────────────────────────────────────────────────────────┘
```

Figure 10. Example of the Final Screen Displayed After Defining Random Perturbations. In this example, the user has opted to define random perturbation parameters for the first atmospheric variable only

1. A fixed positive seed generates the same sequence of random numbers

2. Different positive seeds generate different sequences of random numbers

3. A negative seed restarts the random sequence.

SENTRAN7 allows users to select from two types of random number sequences for correlated and uncorrelated random perturbation profiles. These are:

1. Reinitialize the random number sequence

2. Use fully random numbers.

The first option is often desirable because it allows users to duplicate their sensitivity studies from different SENTRAN7 sessions. The second option is acheived in SENTRAN7 by means of a system call to the computer clock which provides a positive variable seed.

The menu to select the type of random number sequence, which is shown in Figure 11, automatically appears immediately after a user defines the random perturbation parameters. Users should type '1' to reinitialize the random number sequence and '2' to use fully random numbers. Once a random number sequence has been selected, it will be used in all subsequent compilations to generate random perturbation profiles, until another random number sequence is selected.

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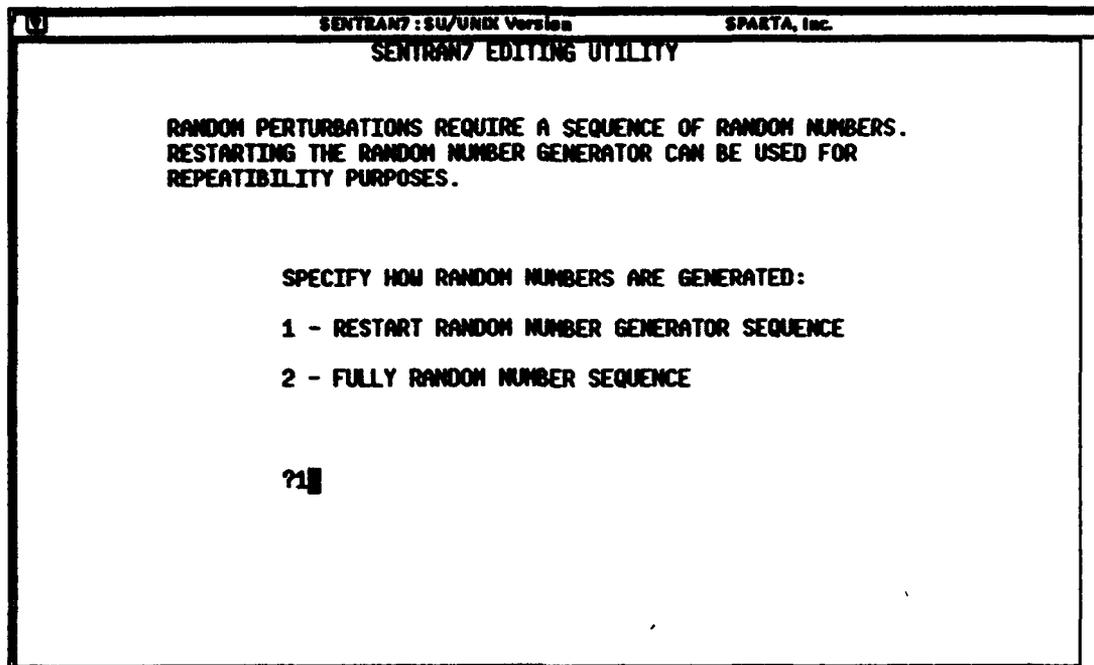
Figure 11. Menu Used to Select the Random Number Sequence To Be Used When Generating Correlated and Uncorrelated Random Perturbation Profiles. In this example, the user has opted to restart the random number generator

4.2.3.5 Invoke Deterministic and Random Perturbations

To invoke deterministic and random perturbations, the user must enter SEN-TRAN7's Edit Module and define the sensitivity problem. (Recall that in order to make use of deterministic and random perturbations, a user must employ a user-defined atmosphere. This class of problems requires MODEL=7 on Card 1.) Specifically, the place to invoke deterministic and random perturbations is in the Edit Card 2C menu, immediately after having specified the file name for user-defined atmospheric profiles (*i.e.*, the *.PRO* file). Users must first proceed to the atmospheric variable that they want to impose the perturbations on. To invoke deterministic perturbations, enter 'det1' for the first deterministic perturbation or 'det2' for the second deterministic perturbation. Similarly, to invoke random perturbations, enter 'ran1' for the first random perturbation or 'ran2' for the second random perturbation. Examples of the commands to impose the first deterministic and random perturbations on temperature are shown in Figures 12 and 13, respectively. After typing 'det1', 'det2', 'ran1', and 'ran2' for the desired atmospheric variables, users can continue with their SENTRAN7 session.

At this point, it is worth mentioning that SENTRAN7 allows users to repeat 'det1', 'det2', 'ran1', and 'ran2' for more than one atmospheric variable in the Edit Card 2C menu, in order to impose the same deterministic or random perturba-

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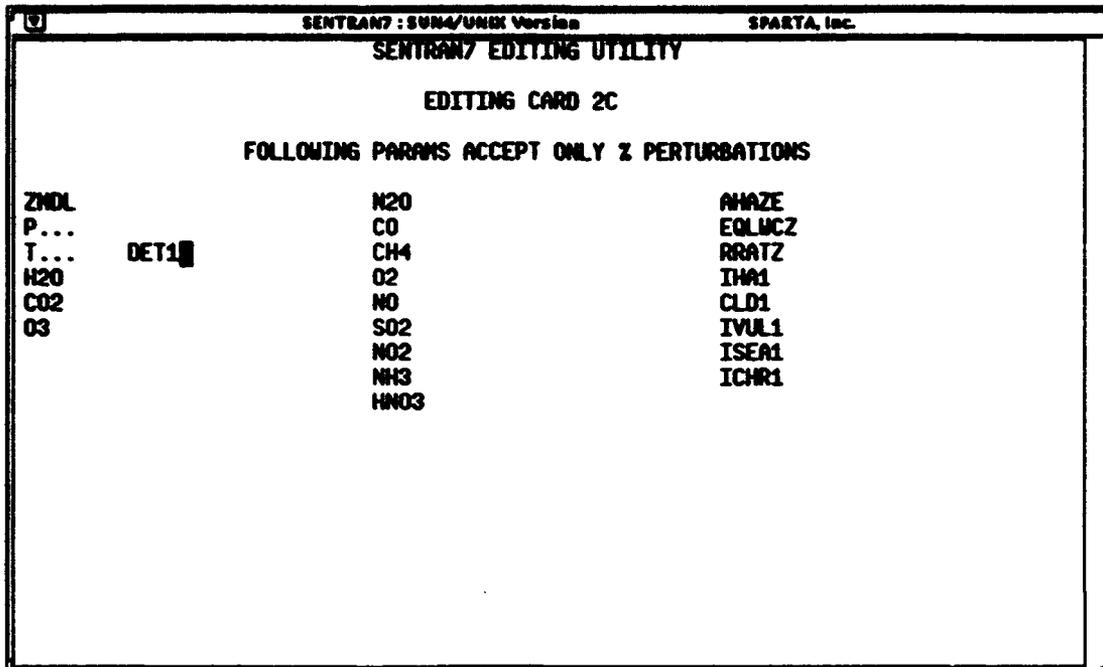
Figure 12. Menu Showing the Command Used To Invoke Deterministic Perturbations on the Edit Card 2C Menu. In this example, the user has opted for the first deterministic perturbations on temperature
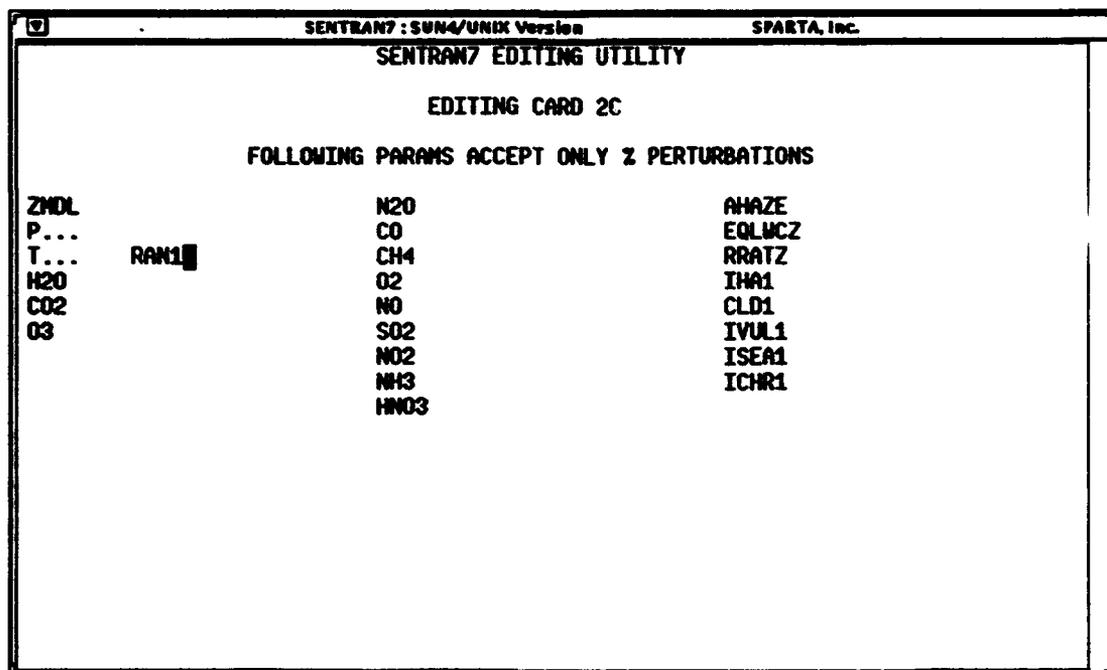
Figure 13. Menu Showing the Command Used To Invoke Random Perturbations. In this example, the user has opted for the first random perturbations on temperature

tion parameters. However, the percent perturbation amounts for two atmospheric variables with the same 'ran1', or 'ran2' command will differ layer-by-layer because they access different portions of the random number sequence. Also, note that users can still enter a percent perturbation in this menu, in order to perturb all layers by the given percentage.

4.2.3.6 Files With Deterministic and Random Perturbation Profiles

SENTRAN7 provides the means to create files that contain deterministic and random perturbation profiles. The standard 'write' command, which creates a *3D* file in the Edit Card 2C menu, is available for deterministic perturbations after users have entered 'det1' or 'det2' for an atmospheric variable. The procedure is the same as that for percent perturbations (see Section 4.2.9). The root names for the *3D* files with deterministic perturbations are the same as those for the standard 'write' command.

Because the generation of random perturbation profiles only takes place in SENTRAN7's Compile Module, the 'write' command has been **disabled** for random perturbations after users have entered 'ran1', or 'ran2' for an atmospheric variable. As a replacement, SENTRAN7 automatically tabulates these values in a fixed file named *RANDOM1.DAT* whenever a compile command is issued. SENTRAN7 also provides a statistical analysis of randomly perturbed profiles so users can decide if the code has matched the desired specifications within allowable tolerances. Specifically, SENTRAN7 calculates the mean, standard deviation, percent standard deviation, and correlation length of the randomly perturbed profiles as a function of altitude. The results are automatically tabulated in a fixed file named *RANDOM2.DAT* whenever a compile command is issued. Table 5 gives a summary of files that contain deterministic and random perturbation profiles.

Table 5. General Information About Files That Contain Deterministic and Random Perturbation Profiles

	DETERMINISTIC PERTURBATIONS	RANDOM PERTURBATIONS
'write' Command	Yes	No
File Name	*3D*	*RANDOM1.DAT* (Perturbation Profiles)
		RANDOM2.DAT (Statistical Analysis)
Creation of File	Optional	Always
Time of Creation	At 'write' command	During compilation

An example of output written to *RANDOM1.DAT* is shown in Figure 14. If a sensitivity study has more than one randomly perturbed atmospheric variable,

additional profiles are appended at the bottom of *RANDOM1.DAT*. Note that *RAN-DOM1.DAT* is overwritten each time a compile command is performed. Thus, the contents of *RANDOM1.DAT* represent the most recent *INP* file to be created. The contents of *RANDOM1.DAT* cannot be plotted in SENTRAN7's Graph & Analyze Module.

An example of output written to *RANDOM2.DAT* is shown in Figure 15. If a sensitivity study has more than one randomly perturbed atmospheric variable, additional analyses are appended at the bottom of *RANDOM2.DAT*. Also, note that *RANDOM2.DAT* is overwritten each time a compile command is performed. Consequently, the contents of *RANDOM2.DAT* represent the most recent *INP* file to be created. The contents of *RANDOM2.DAT* cannot be plotted in SENTRAN7's Graph & Analyze Module. Note that statistical analysis always corresponds to the randomly perturbed profiles in *RANDOM1.DAT*.

4.2.3.7 Restrictions in the *PRO* File

To apply deterministic and random perturbations to an atmospheric variable, layer amounts in the *PRO* file must be defined numerically. That is, the user cannot specify model atmosphere values (*i.e.*, 1,2,3,4,5,6) in the JCHAR character array because these values override the numerical input (see the Users Guide for LOWTRAN7). Additionally, all layer amounts for the atmospheric variable should be specified using the same physical units when the random perturbation option is desired. It is the users responsibility to ensure that these conditions are satisfied.

4.2.3.8 Limited Consistency Checks

It is worth emphasizing that deterministic and random perturbations are directly applied to the *PRO* file that is specified in the Edit Module. Currently, SENTRAN7 performs no "cross checking" of a *PRO* file from the Define Perturbations Module. Consequently, a deterministic perturbation for the 30th layer will not be used if the *PRO* file only has 25 layers in it. Similarly, when altitude dependent correlation lengths for random perturbations are specified by means of a file with a *RND* extension (see Section 4.2.3.3 and Appendix A), the number of layers in the *RND* file must match those in the *PRO* file. Also, the units of $L(z)$ must be km and the units of $\sigma(z)$ must match those in the *PRO* file for the atmospheric parameter to be perturbed. It is the users responsibility to ensure that these conditions are satisfied.

```
  0.000 2.997E+02 3.024E+02 3.051E+02 2.986E+02 3.021E+02
  1.000 2.937E+02 2.952E+02 2.899E+02 2.929E+02 2.867E+02
  2.000 2.877E+02 2.855E+02 2.878E+02 2.833E+02 2.858E+02
  3.000 2.837E+02 2.839E+02 2.862E+02 2.861E+02 2.821E+02
  4.000 2.770E+02 2.801E+02 2.775E+02 2.804E+02 2.808E+02
  5.000 2.703E+02 2.718E+02 2.698E+02 2.735E+02 2.670E+02
  6.000 2.636E+02 2.649E+02 2.639E+02 2.612E+02 2.612E+02
  7.000 2.570E+02 2.594E+02 2.597E+02 2.547E+02 2.569E+02
  8.000 2.503E+02 2.514E+02 2.530E+02 2.520E+02 2.486E+02
  9.000 2.436E+02 2.440E+02 2.462E+02 2.389E+02 2.457E+02
 10.000 2.370E+02 2.354E+02 2.358E+02 2.386E+02 2.373E+02
 11.000 2.301E+02 2.330E+02 2.291E+02 2.318E+02 2.311E+02
 12.000 2.236E+02 2.205E+02 2.198E+02 2.227E+02 2.211E+02
 13.000 2.170E+02 2.151E+02 2.175E+02 2.176E+02 2.181E+02
 14.000 2.103E+02 2.114E+02 2.055E+02 2.119E+02 2.091E+02
 15.000 2.037E+02 2.031E+02 2.054E+02 2.067E+02 2.017E+02
 16.000 1.970E+02 1.999E+02 1.999E+02 1.951E+02 2.003E+02
 17.000 1.948E+02 1.970E+02 1.947E+02 1.947E+02 1.948E+02
 18.000 1.988E+02 1.985E+02 2.000E+02 1.967E+02 1.979E+02
 19.000 2.027E+02 2.026E+02 2.008E+02 2.029E+02 2.037E+02
 20.000 2.067E+02 2.063E+02 2.079E+02 2.057E+02 2.077E+02
 21.000 2.107E+02 2.125E+02 2.109E+02 2.126E+02 2.134E+02
 22.000 2.146E+02 2.125E+02 2.138E+02 2.157E+02 2.133E+02
 23.000 2.170E+02 2.140E+02 2.184E+02 2.187E+02 2.164E+02
 24.000 2.192E+02 2.220E+02 2.196E+02 2.210E+02 2.215E+02
 25.000 2.214E+02 2.235E+02 2.211E+02 2.234E+02 2.195E+02
 30.000 2.323E+02 2.328E+02 2.349E+02 2.336E+02 2.299E+02
 35.000 2.431E+02 2.465E+02 2.419E+02 2.408E+02 2.458E+02
 40.000 2.540E+02 2.538E+02 2.579E+02 2.559E+02 2.577E+02
 45.000 2.648E+02 2.643E+02 2.647E+02 2.682E+02 2.694E+02
 50.000 2.702E+02 2.704E+02 2.718E+02 2.688E+02 2.717E+02
 70.000 2.189E+02 2.184E+02 2.212E+02 2.229E+02 2.251E+02
100.000 1.907E+02 1.896E+02 1.897E+02 1.918E+02 1.874E+02
```

Figure 14. Example of the *RANDOM1.DAT* File Which Contains Tabulated Values of Randomly Perturbed Profiles. In this example, temperature was perturbed and five profiles were generated. The first column is altitude as defined in the *.PRO* file and the other columns are perturbed profiles where the first profile is the reference profile

As mentioned in Section 2.6.3, users must exercise caution when they perturb pressure and/or temperature profiles with the 'det1', 'det2', 'ran1', and 'ran2' commands. That is, altitude, pressure, and temperature are related by the hydrostatic relationship and, consequently, perturbing pressures while holding temperatures at their reference values (or vice versa) is not strictly correct. Therefore, it is recommended that users only specify small perturbations so departures from hydrostatic equilibrium are relatively minor.

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```
SENTRAN7 ANALYSIS OF PROFILES WITH RANDOM PERTURBATIONS


NUMBER OF PERTURBED PROFILES (EXCLUDING REFERENCE PROFILE):    4


             REFERENCE   AVERAGE OF    STD DEV OF     100*RATIO OF
ALTITUDE     PROFILE     PERTURBATIONS PERTURBATIONS  STD DEV/AVERAGE
  0.000      2.997E+02   3.020E+02     2.642E+00        0.875
  1.000      2.937E+02   2.912E+02     3.686E+00        1.266
  2.000      2.877E+02   2.856E+02     1.834E+00        0.642
  3.000      2.837E+02   2.846E+02     1.950E+00        0.685
  4.000      2.770E+02   2.797E+02     1.521E+00        0.544
  5.000      2.703E+02   2.705E+02     2.789E+00        1.031
  6.000      2.636E+02   2.628E+02     1.890E+00        0.719
  7.000      2.570E+02   2.577E+02     2.352E+00        0.913
  8.000      2.503E+02   2.513E+02     1.889E+00        0.752
  9.000      2.436E+02   2.437E+02     3.340E+00        1.371
 10.000      2.370E+02   2.368E+02     1.447E+00        0.611
 11.000      2.301E+02   2.313E+02     1.641E+00        0.710
 12.000      2.236E+02   2.210E+02     1.235E+00        0.559
 13.000      2.170E+02   2.171E+02     1.327E+00        0.611
 14.000      2.103E+02   2.095E+02     2.944E+00        1.405
 15.000      2.037E+02   2.042E+02     2.252E+00        1.103
 16.000      1.970E+02   1.988E+02     2.444E+00        1.229
 17.000      1.948E+02   1.953E+02     1.120E+00        0.574
 18.000      1.988E+02   1.983E+02     1.399E+00        0.706
 19.000      2.027E+02   2.025E+02     1.233E+00        0.609
 20.000      2.067E+02   2.069E+02     1.094E+00        0.529
 21.000      2.107E+02   2.123E+02     1.033E+00        0.487
 22.000      2.146E+02   2.138E+02     1.360E+00        0.636
 23.000      2.170E+02   2.169E+02     2.155E+00        0.994
 24.000      2.192E+02   2.210E+02     1.041E+00        0.471
 25.000      2.214E+02   2.219E+02     1.928E+00        0.869
 30.000      2.323E+02   2.328E+02     2.118E+00        0.910
 35.000      2.431E+02   2.437E+02     2.831E+00        1.162
 40.000      2.540E+02   2.563E+02     1.890E+00        0.737
 45.000      2.648E+02   2.667E+02     2.517E+00        0.944
 50.000      2.702E+02   2.707E+02     1.392E+00        0.514
 70.000      2.189E+02   2.219E+02     2.835E+00        1.278
100.000      1.907E+02   1.896E+02     1.794E+00        0.946
```

Figure 15. Example of the *RANDOM2.DAT* File Which Contains a Statistical Analysis of Randomly Perturbed Profiles. In this example, temperature was perturbed and five profiles were generated. Note that the reference profile is shown in the file, but it is not included in the analysis

4.2.4 Edit Module

The Edit Module of SENTRAN7 provides a flexible means of defining MOD-TRAN input cards. The SENTRAN7 editor permits the entry of atmospheric data and commands for data perturbation. The user is reminded that MODTRAN's input philosophy is based on "cards" of data. Each "card" relates to data or operating conditions of a specific type. SENTRAN7 retains the MODTRAN input card philosophy and SENTRAN7's editor emulates MODTRAN's logical flow through the input card images.

4.2.4.1 General Information

To enter the editor, the user should enter '2' or 'edit' at the Main Menu prompt. The SENTRAN7 Edit Module then provides the user with a series of screens from which the user can set up or edit the simulation conditions. Figure 16 provides an example of a screen displayed while editing a MODTRAN "card." The example is for Card 1 of the MODTRAN input cards. The name of the current card image appears at the top of the editing screen, while the name of the MODTRAN input variables appear along the left hand column. Values for each of the MODTRAN inputs appear to the immediate right of the list of names, along with any perturbation instructions. The terminal's cursor will appear to the left of the variable which is currently being edited, and data entry is accomplished by typing over the current field. In Figure 16, MODEL is the parameter currently being edited. Variables that are marked with an "*" are subject to certain restrictions. The input parameters marked with an "*" in the Edit Module, cannot be perturbed in some cases because their perturbation creates different flows through the input card images.

4.2.4.2 Movement in the Edit Menus

In the Edit Module, the user hits RETURN to move down the current card image, line-by-line. In addition, there are several input strings that SENTRAN7 reserves for cursor control. These commands are listed in Table 6. Note in Table 6, that the "n" values are optional, and their absence implies n=1.

While in the Edit Module, the user can use the UP command to go back to a previous parameter. Simply typing 'up' and RETURN will move the cursor up one line. To move back more than one line, the user should enter 'up' and the number of lines to move. For example, the command, 'up 2', will move the cursor back two lines. Similarly, to move ahead, the user should enter the "down" command, 'dn', and the number of lines to move down (if greater than one).

If the user has made all the necessary changes to a card and wants to move quickly to the next card image, the PAGE DOWN command, 'pd', is used. Before proceeding to the next card image, the user will be prompted to check that all the parameters on the current card have been set as desired. Similarly, if the user

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Figure 16. Example of a SENTRAN7 Editing Screen for MODTRAN Card 1

Table 6. List of Cursor Control Commands in the Edit Module of SENTRAN7

COMMAND	ACTION
UP n[1]	Move cursor up n lines
DN n	Move cursor down n lines
PU	Move to previous major[2] card image (PAGE UP)
PD	Move to next major card image (PAGE DOWN)
END	End editing session, goto Main Menu

[1] n is optional; its absence means $n = 1$

[2] Major cards are Card 1, 2, 3, 4

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wants to move back to the previous card image, the PAGE UP command, 'pu', is used. This command will move the user to the previous major card image. Note that the major cards are Cards 1, 2, 3, and 4. To quickly end the editing session, enter 'end' and press RETURN. The user is then returned to the Main Menu.

As editing is taking place, the user will notice that some MODTRAN input cards and some variables within a card will not be made available for editing. Instead, the cursor will skip over certain parameters or certain input cards will not be displayed. This is because SENTRAN7's editor emulates MODTRAN's flow through the input cards. Specifically, some MODTRAN parameters are not available unless certain other conditions have already been set. For example, on Card 1, if the execution mode parameter, IEMSCT, is set for transmittance mode (IEMSCT=0) or directly transmitted solar irradiance (IEMSCT=3), then multiple scattering is not allowed. Therefore, the IMULT parameter, which specifies multiple scattering, is set to zero and SENTRAN7 does not let the user edit this parameter. This feature aids the user by eliminating unnecessary and potentially misleading inputs. In addition, the user is not asked to edit certain cards unless they are needed. For example, Card 2C is not edited unless the model parameter is set for meteorological data (MODEL=0) or a new model atmosphere (MODEL=7) and radiosonde data are to be read in at execution time (IM=1). This again eliminates unnecessary input and serves as a form of debugging tool, in that the user who wants to edit a certain card image is first forced to set the appropriate flag on a previous card image as required by MODTRAN.

It is important to note that if the user tries to move up or down via the 'up' and 'dn' commands to a line that cannot be edited, the cursor will not move from the current line. The user must enter a number of lines to move with the 'up' and 'dn' commands so that the cursor will be placed on a line that is currently editable.

After each card has been edited, the user is prompted to check that all the parameters for that card have been set as desired, as shown in Figure 17. Before proceeding to the next card image, the user should check the values set for the current card. If the user wants to change a value, the user can enter 'n' to return to the top of the current card being edited. If the user accepts the default 'y', the screen is updated to display the next card image to be edited.

4.2.4.3 Data Entry

Entry at each line of a card image consists of two elements. The first is known as the nominal value, while the second is known as a perturbation directive. The nominal value, in the absence of a perturbation directive, is the value which SENTRAN7 passes to MODTRAN upon execution. The perturbation directive is a statement which is interpreted by SENTRAN7's Compiler Module to produce a sequence of values to use for that particular parameter during a MODTRAN

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```
                    SENTRAN7 EDITING UTILITY
                        EDITING CARD 1

FOLLOWING PARAMS. USE A PERTURBATION LIST (* IMPLIES PERTURBATION RESTRICTIONS)

MODEL *     6
ITYPE *     1
IEMSCT*     0
IMULT *     0
M1 ...      0
M2 ...      0
M3 ...      0
M4 ...      0
M5 ...      0
M6 ...      0
MDEF..      0
IM ...*     0
NOPRT *     0

FOLLOWING PARAMS. USE A PERTURBATION VALUE
TBOUND      0.000
SALB        0.000
ALL PARAMETERS FOR CARD 1 O.K. (Y/N) [N]
```

Figure 17. Prompt Message Used to Check the Variables on a Given MODTRAN Input Card. The example given is for MODTRAN Card 1

run. The nominal value, in the presence of a perturbation directive, is the value perturbed.

Data entry is accomplished by simply typing over the current field. Note that SENTRAN7 is case insensitive and, therefore, data entry can be accomplished in either lower or upper case. After the input line is entered, SENTRAN7 internally converts the string to upper case and displays the line in a format that insures an organized appearance.

4.2.4.4 Perturbing Data

SENTRAN7 permits symbolic manipulation of input card variables through a simple interpreted language data entry format. Seven basic perturbation syntaxes are supported, each possessing a different physical interpretation, allowing the user to select the syntax which best fits the user's needs. The syntaxes supported are shown in Table 7. The nominal value is the first value entered in the command. Terms appearing in square brackets "[]" in Table 7 are optional. The '%', '+/-', 'to', '*', 'det1', 'det2', 'ran1', and 'ran2' terms are actual elements within the command string. Examples of the perturbation commands and how they can be used, are shown in Table 8. Note that these perturbations are not limited to the parameters shown in Table 8. These parameters were chosen only to give specific examples of how each of the perturbation commands can be used. Additional information about the 'det1', 'det2', 'ran1', and 'ran2' commands is given in

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Table 7. List of SENTRAN7 Perturbation Command Syntaxes in the Edit Module

TYPE OF PERTURBATION	SYNTAX FORMAT
%[1]	*nominal value %value*
+/-	*nominal value +/- value*
Iteration	*nominal value [start]*[2] *TO final [STEP n]*
List	*nominal value value2 value3 ...*
Use Previous	*nominal value ∗*
Deterministic[3]	*DET1, DET2*
Random [3]	*RAN1, RAN2*

[1] On Card 2C and 2D, a nominal value is not allowed with a percent perturbation

[2] Terms in "[ ]" are optional

[3] Allowed with Card 2C parameters only

Table 8. Examples of Perturbation Commands. Information about the DET1, DET2, RAN1, and RAN2 perturbation commands is given in Section 4.2.2.

SAMPLE PARAMETER	PERTUBATION COMMAND	SEQUENCE PRODUCED
H1	5.0 %20	4.0, 5.0, 6.0
H2	8.0 +/- 2	6.0, 8.0, 10.0
ANGLE	45.0 TO 47	45.0, 46.0, 47.0
RANGE	10.0 TO 20 STEP 5	10.0, 15.0, 20.0
VIS	5.0 0 TO 10 STEP 5	0.0, 5.0, 10.0
MODEL	4 3 6	4, 3, 6

Section 4.2.2.

As an example, to produce a percent perturbation of a parameter, the user would type a nominal value followed by a '%' sign and the amount of the desired percent perturbation. For example, to perturb the parameter H1 on Card 3, with a nominal value of 5.0 by 20 percent, the user would enter the command '5.0 %20',

as shown in the first example in Table 8. When compiled, the input file contains MODTRAN input conditions for the H1 parameter at 4.0, 5.0, and 6.0 km. Note that for Cards 2C and 2D, where only percent perturbations are allowed, the user cannot enter a nominal value. Instead, the user only enters '%' followed by the amount of the desired percent perturbation. The nominal values are read from the input files provided for Cards 2C and 2D, the trace gas and aerosol attenuation profiles, respectively.

The second perturbation type allows the user to explicitly specify an offset to the nominal value. In this case, the user enters the nominal value and then '+/-' followed by the offset value. For example, to perturb the parameter H2 on Card 3 with a nominal value of 8.0 by ± 2, the user would enter '**8.0 +/- 2**', as shown in the example in Table 8. This command would produce the sequence "6.0, 8.0, 10.0", for the H2 parameter.

The user can also specify an iterative perturbation by entering a start and final value and a step size, with the default step size being equal to one. One example of this type of perturbation is shown in Table 8 for the ANGLE parameter on Card 3. For example, if the user enters the command '**45.0 TO 47**' for the ANGLE parameter, MODTRAN will perform calculations with the parameter ANGLE set at 45.0, 46.0, and 47.0 degrees. The user can also explicitly specify a step size for the iterative perturbation, as shown in the example in Table 8 for the RANGE parameter on Card 3. In this example, the user enters '**10.0 TO 20 STEP 5**', to produce the sequence "10.0, 15.0, 20.0". Note that the nominal value for the iterative perturbation type, can be different than the start value of the iteration. An example of this is shown for the VIS parameter in Table 8. In this example, the user explicitly specifies a nominal value of 5.0 for the VIS parameter on Card 2, and then perturbs the parameter from zero to ten, in steps of five. The command the user would enter is '**5.0   0 TO 10 STEP 5**'. The benefits of specifying a different nominal value will become clear when the compiler options are explained in Section 4.2.5.2. Briefly, the NOMESH option of the SENTRAN7 compiler, perturbs one parameter at a time, holding all other parameters fixed at their nominal values. In the example given here, the VIS parameter will be held constant at 5.0 while other parameters are perturbed. If the user had entered '**0 TO 10 STEP 5**' for the VIS parameter, with no nominal value specified, then the VIS parameter would be held constant at 0.0 while other parameters were perturbed, if compiled with the NOMESH option. Thus, the user may want the nominal value to be different then the starting value of the iteration.

The fourth type of perturbation is to enter a specific list of values. In this case, the user would simply type in the values to use, separated by spaces. This is shown in an example in Table 8 for the MODEL parameter from Card 1.

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The fifth type of perturbation listed in Table 7 allows the user to change the nominal value of a parameter, but keep the old perturbation for that parameter. The user would enter the new nominal value followed by a '*'. For example, to change the nominal value of a particular parameter to 5.0, but keep the previously specified perturbation directive, the user would enter '5 *'. An example of this command is not shown in Table 8 because the sequence produced with this type of perturbation depends on the previously set perturbation directive.

It should be noted that the Edit Module checks that the nominal value entered by the user is within the allowable range for that particular parameter. This is done as the user enters the value. If the value entered by the user is out of range, SENTRAN7 sets the nominal value to the nearest value within range. No warning message is given to the user, although such a feature is possible in future versions of SENTRAN7. Therefore, it is important that the user verify each line after it has been entered. Although the Edit Module checks the nominal value, it does not check that the perturbed values for a particular parameter are physically meaningful and within range. The perturbation values will, instead, be checked within the Compiler Module which will issue a warning at that time.

4.2.4.5 Entry of Perturbations for Card 2C3 Parameters

SENTRAN7 contains an improved algorithm to perturb the IHA1, ICLD1, IVUL1, ISEA1, and ICHR1 parameters on CARD 2C3. Specifically, the Edit Module now accepts integer perturbation values for the IHA1, ICLD1, IVUL1, ISEA1, and ICHR1 parameters. If two or more perturbation values are desired, they must be entered as a list of numbers. (Commands such as 'step' and '+/-' are not accepted.) An example of how to enter perturbations for the IHA1 parameter is shown in Figure 18.

When compiling a sensitivity study involving perturbations of IHA1, ICLD1, IVUL1, ISEA1, and ICHR1, SENTRAN7 now assigns the perturbed values to all layers in the specified .PRO file. This is important to remember because, depending on the scenario, SENTRAN7 may be including perturbed aerosols in layers where users do not want them. Furthermore, LOWTRAN7 and MODTRAN perform some internal "preprocessing" and consistency checks of IHA1, ICLD1, IVUL1, ISEA1, and ICHR1 before performing radiative calculations. (An urban aerosol will not be used in the stratosphere, for example.) Therefore, users should always examine the TAPE6 output to see how the perturbed values of IHA1, ICLD1, IVUL1, ISEA1, and ICHR1 were interpreted by LOWTRAN7 and MODTRAN.

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Figure 18. Example of the Edit Card 2C Menu After the User Has Specified Perturbations for the IHA1 Parameter. Note that the default values for IHA1 are in the *.PRO* file and only the perturbations are entered in the menu.

4.2.4.6 On-line Help Utility

A help utility is available in the Edit Module of SENTRAN7. This help facility provides the user with a simple and fast method for obtaining general information about a parameter on any of the MODTRAN input cards. While in the Edit Module, the user simply types 'help' on the line being edited, and a screen containing a brief description of that particular parameter will appear. Figure 19 shows an example in which 'help' was entered while editing the MODEL parameter on Card 1. It should be stressed that this on-line help facility is meant only to be a quick reference into parameter definitions and possible values and should not be used to provide the overall meaning of the MODTRAN variables. The user is, instead, referenced to the appropriate user guides for LOWTRAN7[1] and MODTRAN.[3]

4.2.4.7 Additional Notes

It is important to note that SENTRAN7 often rounds off numbers incorrectly when displaying nominal values in the Edit Module. This is due to the rounding procedure used in the Edit Module's output format routine. That is, SENTRAN7 utilizes internal character manipulation routines which mimic Fortran format statements, permitting flexible reformatting and mixing of character and numerical data. Often, SENTRAN7 will display a number incorrectly, terminating the number with a set of trailing 9's. For example the value 70 may be displayed as 69.99. While

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```
SENTRAN7 EDITING UTILITY
EDITING CARD 1

FOLLOWING PARAMS. USE A PERTURBATION LIST (* IMPLIES PERTURBATION RESTRICTIONS)

MODEL *  help 0
ITYPE *      1
IEMSCT*      0
IMULT *      0
M1 ..
M2 ..
M3 ..
M4 ..
M5 ..
M6 ..
MDEF.
IM ..
NOPRT

IPOLLN
IBOUN
RALT
```

```
SENTRAN7   SUBSTITUTE  UTILITY                              SPARTA  Inc

SENTRAN HELP UTILITY

'MODEL'                                                       CARD 1

SELECTS ONE OF THE SIX GEOGRAPHICAL-SEASONAL MODEL ATMOSPHERES OR
SPECIFIES THAT USER-DEFINED METEOROLOGICAL DATA ARE TO BE USED:

    = 0  METEOROLOGICAL DATA (HORIZONTAL PATH ONLY)
      1  TROPICAL ATMOSPHERE
      2  MIDLATITUDE SUMMER
      3  MIDLATITUDE WINTER
      4  SUBARCTIC SUMMER
      5  SUBARCTIC WINTER
      6  1976 U.S. STANDARD ATMOSPHERE
      7  NEW MODEL ATMOSPHERE (OR RADIOSONDE DATA)


                    HIT <RETURN> TO CONTINUE
```

Figure 19. Example of an On-line Help Screen That Can Be Called Within Editing Module of SENTRAN7. (Note that the help screen does not appear as a partial overlay during execution as shown in this figure, but rather covers the entire screen)

this problem may be disconcerting (*i.e.*, the number typed is not the number observed) the internal representation of the number is correct and the discrepancy can safely be ignored. An example of this is shown in the tutorials in Chapter 5.

4.2.5 Compile Module

Once data have been entered or edited, it must be compiled, or prepared for assembly as an input file for MODTRAN. This is accomplished by the Compile Module. The SENTRAN7 compiler performs four distinct functions:

1. It generates MODTRAN input files by interpreting edited input according to a special data generation syntax.

2. It optionally provides a list of active molecular absorbers within the spectral region of the MODTRAN calculation.

3. It automatically generates a methodology file with the same first name as the input file generated (example: typing the command 'compile example'

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produces two files, *EXAMPLE.INP* and *EXAMPLE.MTH*, as a MODTRAN input file and methodology file, respectively).

4. It optionally generates a special debug file called *SEN.ERR*.

4.2.5.1 Invoking the Compile Module

Like most of SENTRAN7's main functions, the SENTRAN7 compiler is invoked from the Main Menu, either by typing '3', or any sub-string of the word 'compile', such as 'c'. The user has the option of imbedding compiler arguments (*i.e.*, the input file name and compiler options) within the initial command string, or of being prompted for them on a step-by-step basis. Table 9 shows the allowable compiler commands as typed from the Main Menu and Table 10 gives examples of compiler commands and their effect. The SENTRAN7 Compiler options and their usage are described in more detail in the sections that follow.

Table 9. Allowable Compiler Commands As Typed From the Main Menu

compile [*input file name*] [/MESH /NOMESH /ERROR]
or
3 [*carriage return*] [*input file name*] [/MESH /NOMESH /ERROR]

/MESH Generates All Possible Combinations of Perturbed Input Parameters
/NOMESH Perturbs One Parameter at a Time, Holding All Others Fixed
/ERROR Creates *SEN.ERR* Containing Compile Errors and List of Active Molecular Absorbers

Table 10. Examples of Compiler Commands as Typed From the Main Menu

COMMAND	EFFECT
compile test /m /e	Compiles input file named *TEST.INP* as MESH and generates the error file *SEN.ERR*
3 <RETURN> **test /n**	Compiles input file named *TEST.INP* as NOMESH with no error file
com test.wow	Compiles input file named *TEST.WOW* using last mode (MESH or NOMESH) as default, no error file generated
c test.dumb /m /n /e	Compiles input file named *TEST.DUMB* as NOMESH, demonstrating that MESH and NOMESH are exclusive, with NOMESH taking precedence. An error file is created

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4.2.5.2 MESH and NOMESH Compiler Options

SENTRAN7's compiler supports two options which control how many separate MODTRAN runs are created in the input file. These are the MESH and NOMESH options. To include the MESH option, the user enters '/mesh', or simply '/m', after the name of the input file to be created by the SENTRAN7 compiler. Similarly, to include the NOMESH option, the user enters '/nomesh', or simply '/n', after the input file name. Note that the MESH and NOMESH options are exclusive, that is, only one can be used for compiling an input file. If both options are specified, the NOMESH option takes precedence and the input file will be compiled as NOMESH. Another fact worth noting is that the SENTRAN7 compiler "remembers" the last compilation mode selected and utilizes this as the default mode for subsequent compilation if neither the MESH or NOMESH options are specified.

The MESH option generates all possible combinations of all perturbed input parameters while the NOMESH option perturbs one parameter at a time, holding all other parameters fixed at their nominal values. The difference between the MESH and NOMESH options can be demonstrated in Table 11 which shows the combinations of MODTRAN runs that will be generated by SENTRAN7 when two parameters are simultaneously perturbed. In this example, both parameters are given a nominal value and three perturbation values. A 'M/N' means both the MESH and NOMESH options generate this combination for a MODTRAN run. An 'M' means only the MESH option will compile this combination. The MESH option is most useful for studying synergistic effects arising from the simultaneous perturbation of several parameters, while the NOMESH option generates a smaller data set if more than one parameter is perturbed. If only one parameter is perturbed, or no parameters are perturbed, the MESH and NOMESH options are equivalent.

SENTRAN7 places little restriction on the number of parameters that may be perturbed, although the compiler insures that perturbed values for a particular parameter are physically meaningful. Up to 10 simultaneous perturbations may be realized for each compilation, with each perturbation assuming as many as 100 distinct values (more than 100 distinct values can be generated for each variable in NOMESH form). This feature permits extremely rapid exploration of the sensitivity of different MODTRAN parameters, with the unfortunate side effect of generating enormous quantities of data. In fact, SENTRAN7's capability to generate multiple runs of MODTRAN far outweigh its analysis capabilities, since SENTRAN7 can only graph and analyze the effects of two simultaneous perturbations at a time.

Table 11. Combinations of MODTRAN Runs for the MESH and NOMESH Compiler Options When Two Parameters Are Perturbed. In this example, both parameters have a nominal value and three perturbations

FIRST PARAMETER	SECOND PARAMETER			
	Nominal Value	Perturbation 1	Perturbation 2	Perturbation 3
Nominal Value	M/N[1]	M/N	M/N	M/N
Perturbation 1	M/N	M[2]	M	M
Perturbation 2	M/N	M	M	M
Perturbation 3	M/N	M	M	M

[1] 'M/N' indicates both the MESH and NOMESH options generate this MODTRAN run

[2] 'M' indicates the MESH option only will generate this MODTRAN run

4.2.5.3 Error File Option

Another option supported by SENTRAN7's compiler is the ability to write SENTRAN7 compiler error messages and information on major absorbers within the current spectral interval to a special file. This is the ERROR option in the SENTRAN7 Compiler Module. To include the ERROR option, the user enters '/error', or simply '/e', after the name of the input file to be created by the SENTRAN7 compiler. The ERROR option can be used in combination with the MESH or NOMESH options, or by itself. Selection of the ERROR option causes a list of active absorbers and their spectral range of activity to be written to a file called *SEN.ERR*, along with any compile time errors. As mentioned previously, the SENTRAN7 Compiler Module checks that the perturbed values of each parameter are within range for that particular parameter. If there are values that are not within range, the Compiler Module will issue a warning to the user on the screen indicating the parameter and the value out of range. These error messages can also be written to the file, *SEN.ERR*, by indicating the '/error' option when entering the input file name and compiler options. Thus, the ERROR option serves as a crude analysis tool, as well as a potentially useful debugging aid.

4.2.6 Select Module

The Main Menu Select Module is a feature in SENTRAN7 that allows the user to specify the transmission model to be used in their sensitivity analyses. The user can select whether to execute LOWTRAN7, MODTRAN, or MODTRAN run as LOWTRAN7. SENTRAN7 methodology files will work with any of these options. In order to enter the Select Module the user types '4' or 'select' at the Main Menu

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command line. A submenu will appear, as shown in Figure 20, for choosing which model to run. Enter '1', '2' or '3' in order to run LOWTRAN7, MODTRAN or MODTRAN AS LOWTRAN7, respectively. Note that this option does not actually execute the model code, but instead simply chooses which model will be executed from the Run Module. After a model has been selected, SENTRAN7 internally confirms that the specified executable code exists. To do this, SENTRAN7 checks the configuration file, *DIRECT.ORY*, which contains the directory and names of the LOWTRAN7 and MODTRAN executable codes, as well as the location of MODTRAN's molecular absorption data file called *UFTAPE.DAT*. (Refer to Section 3.4 for more information about the *DIRECT.ORY* file.) SENTRAN7 warns the user if the executable file cannot be found. The user must then exit SENTRAN7 and edit the file *DIRECT.ORY* to correctly indicate where the transmission model executable file is located. If *DIRECT.ORY* does not exist, SENTRAN7 searches the current directory for the appropriate files. Once a model code has been correctly selected, SENTRAN7 returns to the Main Menu.
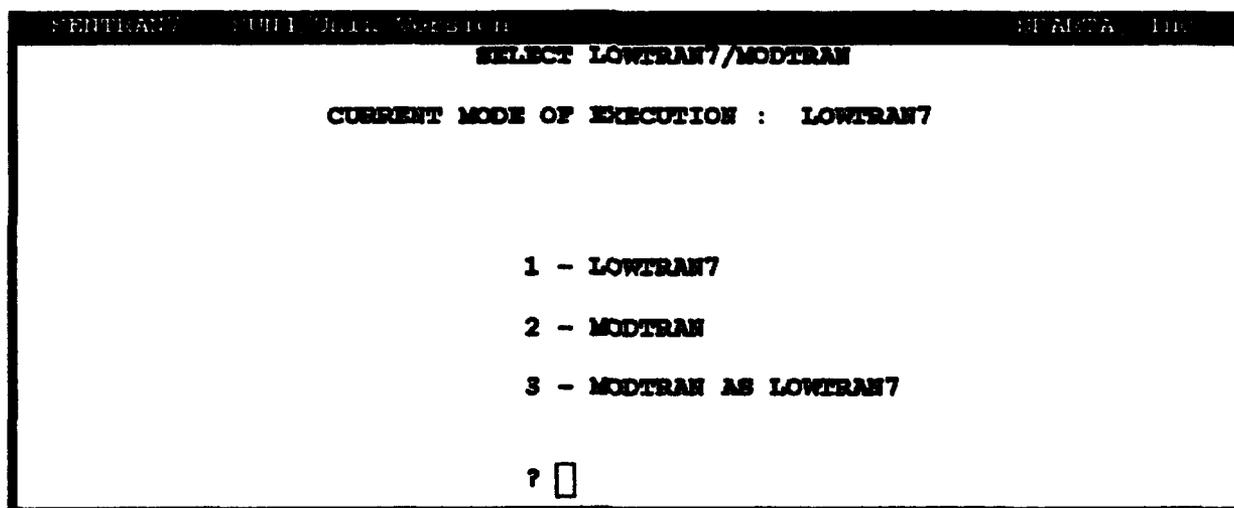
Figure 20. SENTRAN7 Screen Displaying Which Model Program to Execute

4.2.7 Run Module

The Run Module executes the transmission model as specified in the Select Module. The default calculations are performed using the most recent input file to be compiled, although users can specify any input file upon entering the Run Module. The Run Module always produces the standard LOWTRAN7 and MOD-TRAN output files named *TAPE7* and *TAPE8* which can then be interrogated in the Graph and Analyze Module. Additionally, a new feature in SENTRAN7 is the capability to save output files from LOWTRAN7 and MODTRAN as customized file names.

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4.2.7.1 Invoking the Run Module

To select the Run Module, type in '5' or 'run' at the Main Menu command line. SENTRAN7 will then prompt users for the name of the input file, with the default being the last input file compiled. To accept the default input file name, simply hit RETURN. To enter a new input file, type in the new file name and then hit RETURN. A default extension of *.INP* is appended to the file name if no extension is given. To return to the Main Menu, without executing LOWTRAN7 or MODTRAN, type in 'pu' for "page up" at the prompt for an input file name. This will return control to the Main Menu.

Once an input file has been chosen, SENTRAN7 will execute the selected model code and ask the user to please wait until execution is completed. The time required to complete a run will depend on many factors, such as the speed of the host computer and the type of calculation. Once the calculations are completed, hit RETURN to return to the Main Menu.

4.2.7.2 Save Output Files Option

This new feature in SENTRAN7 is particularly useful because LOWTRAN7 and MODTRAN overwrite the standard output files every time the Run Module is selected. Specifically, SENTRAN7 copies the output to customized file names by first identifying the root name of the *.INP* file and then appending the following extensions:

1. *TAPE6* output is copied to *root name.TP6*

2. *TAPE7* output is copied to *root name.TP7*

3. *TAPE8* output is copied to *root name.TP8*.

If the input file for LOWTRAN7 and MODTRAN is named *SPACE.INP*, for example, then the output in *TAPE6, TAPE7*, and *TAPE8* output is copied to *SPACE.TP6, SPACE.TP7*, and *SPACE.TP8*, respectively.

To instruct SENTRAN7 to save the output files, enter '/s' after the name of the input file. An example is shown in Figure 21. When LOWTRAN7 and MODTRAN execute, SENTRAN7 informs users about the customized file names for the output, as shown in Figure 22. Users can deactivate the file saving feature by entering '/n' after an input file name. It is worth noting that the Run Module "remembers" the last run mode selected and utilizes it as the default mode for subsequent runs even if '/s' and '/n' are not specified. Table 12 shows the allowable run commands as typed from the Main Menu.

Finally, it is worth reminding users that Save Output File Option can cause SENTRAN7 to create many files in the users directory. This can become a problem

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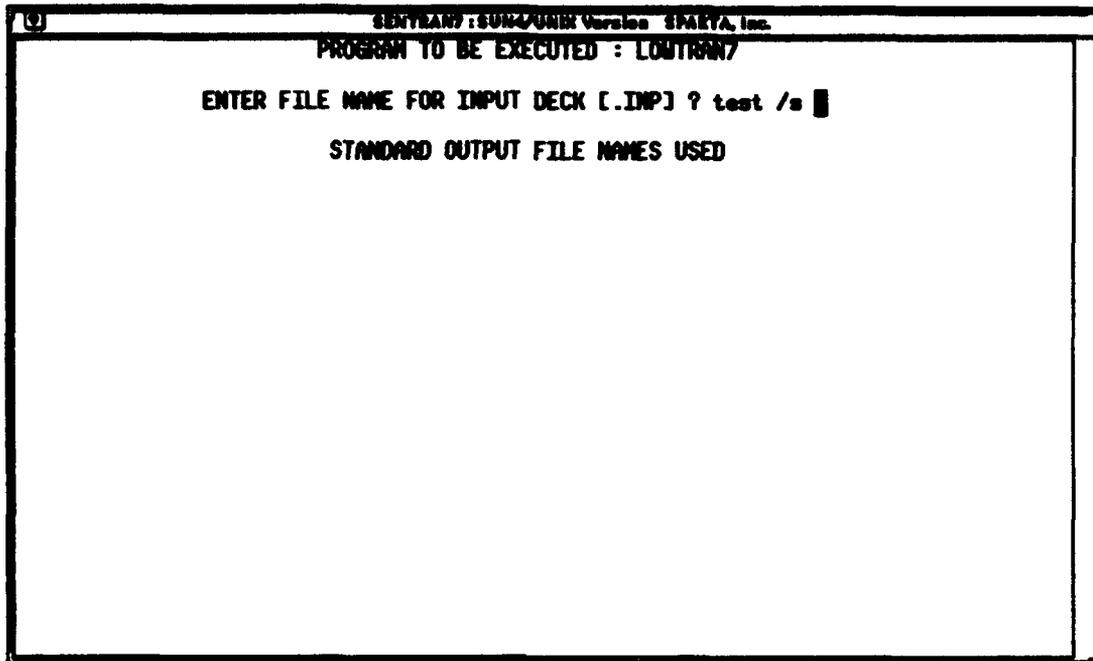
Figure 21. An Example Showing How to Use the Save Output File Option in the Run Module. In this example, the output from *TAPE6*, *TAPE7*, and *TAPE8* is copied to *TEST.TP6*, *TEST.TP7*, and *TEST.TP8*, respectively
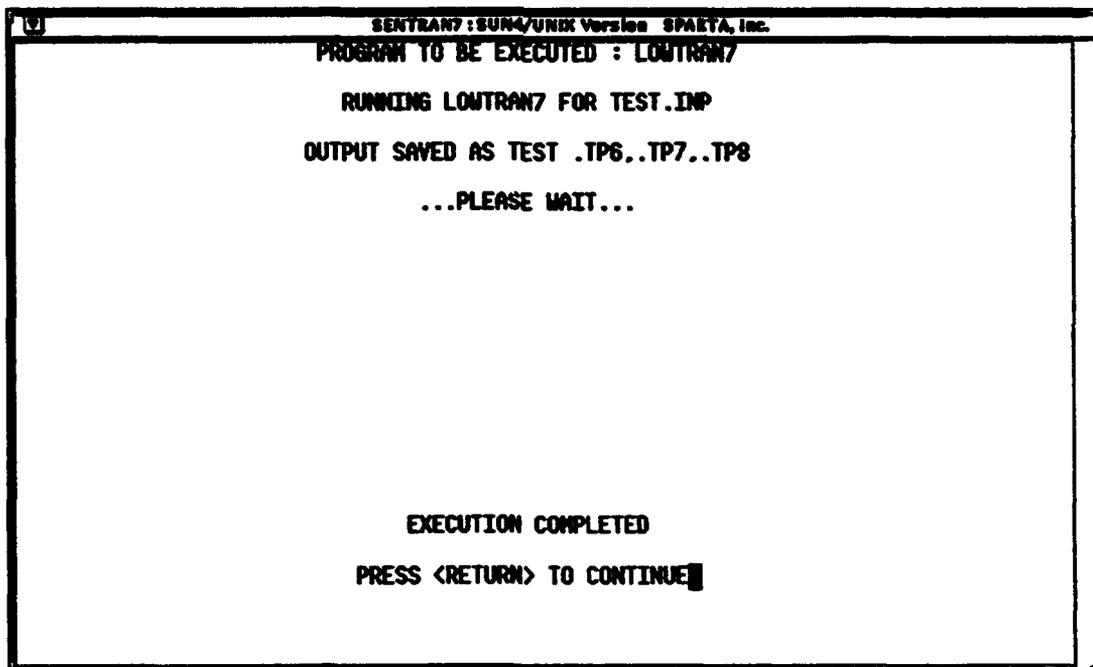
Figure 22. Example of SENTRAN7 Informing Users That Customized File Names Are Being Used to Store Program Output

Table 12. Allowable Run Commands As Typed From the Main Menu

> *run* [*input file name*] [/s /n]
>
> or
>
> **6** [*carriage return*] [*input file name*] [/s /n]

/s Saves LOWTRAN and MODTRAN Output Files as Customized File Names
/n Deactivates the Save Output Files Option

because some sensitivity studies create very large LOWTRAN7 and MODTRAN output files.

4.2.8 Graph and Analyze Module

The Graph and Analyze (G&A) Module in SENTRAN7 provides the user with a powerful tool for analyzing results from a MODTRAN simulation. The options available with the G&A Module allow the user to display and manipulate the output from a given simulation. In particular, the G&A Module provides:

1. Flexible options for extracting and displaying output from MODTRAN calculations and various input files.

2. Tools for data manipulation, analysis, and archiving.

3. Commands for generating graphical plots of data and special graphics files for archival, hard copy, and exporting to commercial graphics and analysis packages.

4.2.8.1 Types of Plots Available

A SENTRAN7 plot of results from a MODTRAN calculation consists of a dependent parameter (such as transmittance, radiance, differential transmittance, etc.) in terms of one or two independent parameters. The dependent parameter is always the z axis. Table 13 lists the type of plots available from the G&A Module and the specific choices for the z axis. As will be discussed further in Section 4.2.8.4, SENTRAN7 imposes restrictions on the choices of the x and y axes among the two independent variables. For this reason, the user is urged to note that SENTRAN7's G&A Module is intended to represent a tool for use in analyzing results from a MODTRAN simulation, but is not intended as the only tool to use.

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Table 13. Type of Plots Available in the SENTRAN7 Graph and Analyze Module

PLOT TYPE	Z AXIS PARAMETER CHOICES
Raw x, y, z	None needed
Transmittance	Total Transmittance Log of Total Transmittance Uniform Mixed Gases Trace Gases Molecular Scattering H_2O H_2O Continuum Ozone (O_3) N_2 Continuum Aerosol and Hydrometeor CO_2 CO CH_4 N_2O O_2 NH_3 NO NO_2 SO_2 HNO_3 Aerosol and Hydrometeor Absorption
Atmospheric Radiance	Total Transmittance Radiance Log of Total Transmittance
Differential Transmittance	DTAU DTAU / Layer Thickness
Black Body Function	DTAU * Black Body Function (DTAU * Black Body Function) / Layer Thickness
Fluxes/Irradiance	Upward Total FLUX Upward Solar FLUX Downward Total FLUX Downward Solar FLUX Direct Solar Irradiance
Solar/Lunar Radiance	Total Transmittance Radiance Path Scattered Single Scattered Total Ground Reflectance Direct Reflected Total Radiance Log of Total Transmittance
Direct Solar Radiance	Total Transmittance Transmitted Solar Incident Solar Log of Total Transmittance

4.2.8.2 Invoking the Graph and Analyze Module

The Graph and Analyze Module extracts its data from MODTRAN's output files based on the current information specified in the Edit Module. Therefore, users should enter the Graph and Analyze Module immediately after running MOD-TRAN, and avoid changing any parameters in the Edit Module.

To enter the G&A Module, type '6' or 'graph', or any sub-string of the word 'graph', such as 'g', at the Main Menu prompt. The initial G&A screen will then appear, as shown in Figure 23.
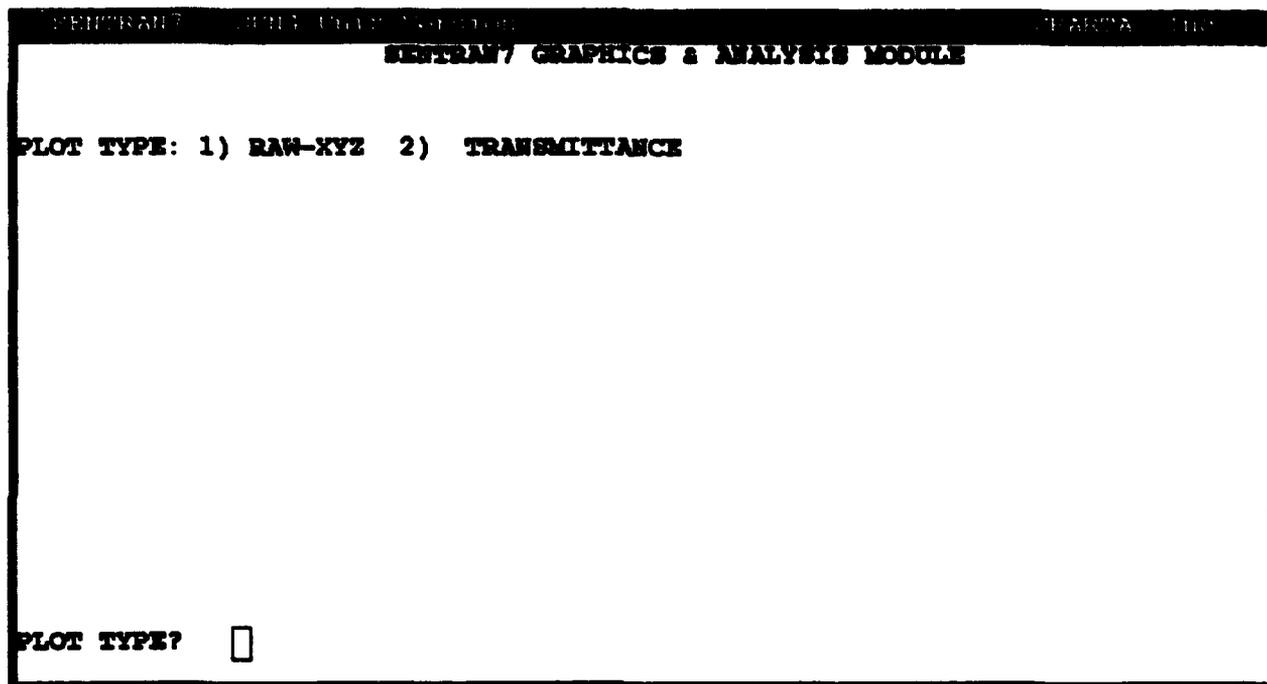
Figure 23. Example of an Initial Screen in the Graph and Analyze Module

4.2.8.3 Specifying the Plotting Parameters

Upon entry into the G&A Module, the user will be prompted for a number of options regarding the sources of data to be plotted. These selections control how SENTRAN7 extracts data from various sources, although from the user's point of view the choices will appear to relate to the selection of two independent axes (x and y) and one dependent axis (z). (See Table 13 for a description of the types of plots available.)

For all plot types, the user is prompted for the output file in which to find the data. For all cases except when plotting a raw x, y, z data file, SENTRAN7 will provide a default file name (*TAPE7.OUT* or *TAPE8.OUT*). The default file name given corresponds to the last LOWTRAN7 or MODTRAN output file produced.

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Whether the default file name is *TAPE7.OUT* or *TAPE8.OUT* will depend on the z axis parameter chosen to plot. To accept the default file name the user should simply hit RETURN. To plot data from a previous LOWTRAN7 or MODTRAN run, the user should enter the output file name and then hit RETURN.

4.2.8.4 Restrictions Imposed by the Graph and Analyze Module

When selecting the plotting parameters, the Graph and Analyze Module of SENTRAN7 imposes some restrictions on the choices available. For example, if the user selects the differential transmittance plot type, DTAU, the G&A Module automatically sets the x axis to atmospheric layer number and the y axis to wavenumber or wavelength. These axes choices are "hardwired" into the code and cannot be changed by the user. Other graphing restrictions are imposed based on the number of parameters being perturbed and the choice of MESH or NOMESH options. Appendix D contains a more detailed description of the logic flow of the plotting options and how and when these restrictions are established.

It is recognized that these restrictions may be frustrating to the user and may represent choices the user did not want to make. These restrictions were established in the original version of SENTRAN developed for LOWTRAN6 and resources were not available to change them under this effort. It is hoped that in future revisions to SENTRAN7 these restrictions can be lessened or eliminated.

4.2.8.5 Commands Available With the Graph and Analyze Module

Once the user has responded to the questions regarding data sources, the G&A Module enters a special loop that interprets single line commands and immediately executes them in order to manipulate and plot the data set. Commands are always issued from a text screen known as the command screen, while plots are displayed on a special graphics screen. Figure 24 shows a typical G&A command screen and Figure 25 shows a typical graphics screen. Note that commands need not be typed in their entirety, provided the shortened command matches the first several letters of the desired command and does not match any other command. The commands in the G&A Module can be divided into three main groups: 1) numerical commands, 2) plotting commands, and 3) I/O and control commands.

The numerical commands perform common arithmetic manipulations on the data set. Table 14 lists all of the numerical commands that enable the user to analyze and manipulate the data. These commands permit numerical differentiation and common numerical conversions to be carried out. When a numerical operation or conversion is applied to an axis, the axis label is modified accordingly. For example, if the z axis label is "TRANSMITTANCE", and the user performs a log conversion on the z axis, then the z axis label will be "LOG TRANSMITTANCE". This change is reflected both on the plots and on the command screen.

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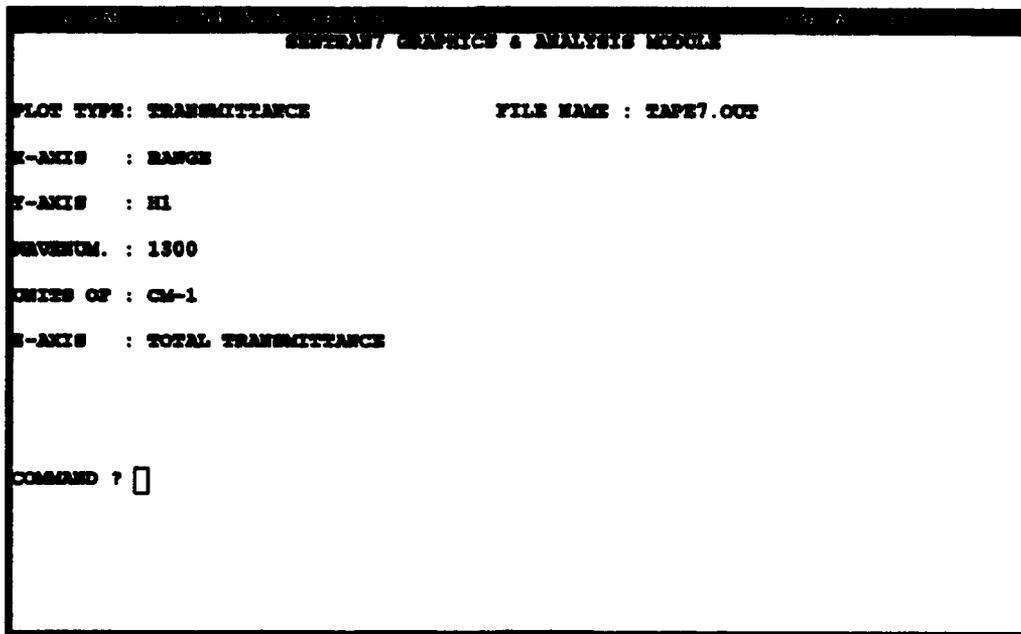
Figure 24. An Example of a Submenu in the SENTRAN7 Graph and Analyze Module Used to Define the Parameters To Be Plotted

X :	RANGE	1.0000E+00 TO	1.0000E+01	(TICK=	1.0)
Y :	H1	0.0000E+00 TO	2.0000E+01	(TICK=	2.0)
Z :	TOTAL TRANSMITTANCE	0.1700E-02 TO	0.9836E+00	(TICK=0.0981)
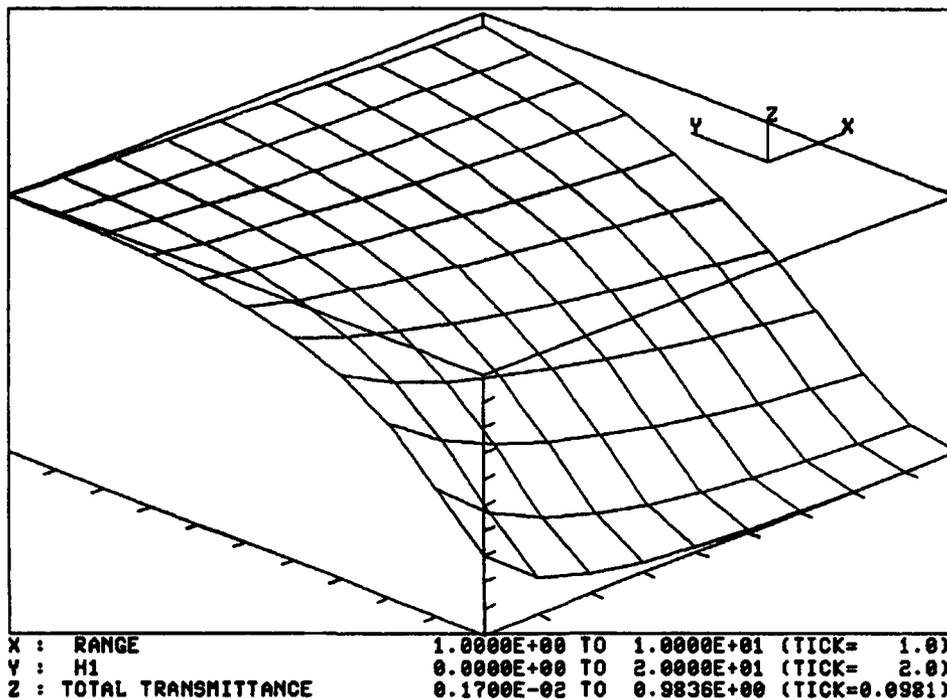
Figure 25. An Example of a Graph from the SENTRAN7 Graph and Analyze Module

Table 14. List of Numerical Commands in Graph and Analyze Module

COMMAND	ARGUMENTS	DESCRIPTION
A2T	NONE	Optical Depth to Transmittance Transformation Transform z axis according to $z=\exp(-z)$
DX	NONE	Compute partial derivative of the data set with respect to the x axis
DY	NONE	Compute partial derivative of the data set with respect to the y axis
DDX	NONE	Compute second partial derivative of the data set with respect to the x axis
DDY	NONE	Compute second partial derivative of the data set with respect to the y axis
DYDX	NONE	Compute cross derivative of the data set with respect to the y axis and then the x axis
DXDY	NONE	Compute cross derivative of the data set with respect to the x axis and then the y axis
LOG	[X][Y][Z]	Transform all coordinates of the named axis to their log values (Example: 'log x')
MAXIMUM	NONE	Write the maximal z values on the screen along with their x,y coordinates
MEAN	NONE	Compute and display the mean z axis value
MINIMUM	NONE	Write the minimal z values on the screen along with their x,y coordinates
NOSORT	[X][Y]	Suppress SENTRAN's tendency to sort data into increasing order (Example: 'nosort x')
SWAP	NONE	Swap the x and y axes
T2A	NONE	Transmittance to Optical Depth Transformation Transform z axis according to $z=\log(1/z)$

The plotting commands provide the user with a means to control certain aspects of the graphical presentation of the data set. Table 15 lists the plotting commands available in the G&A Module of SENTRAN7. The main plotting command is the 'plot' command. The 'plot' command initiates plotting of the data set. The user must provide an argument consisting of a file name to which graphics data will be written and/or the reserved argument 'vt240', which will cause the plot to be sent to the terminal screen. The plot file is automatically given a *.TEK* extension if no extension is supplied by the user. Note that the user can specify both a file

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name and the reserved argument 'vt240' in order to have the graph written to both a file and the screen. If the graph is a 3D plot, the user will also be prompted for rotation angles for the axes. The user may enter these values in free format or press the RETURN key to accept the values which are currently displayed in the field. The first angle is a counterclockwise rotation about the original z axis, while the second angle is a counterclockwise rotation about the x axis (*i.e.*, tilt out of the screen). These rotation angles are often adjusted slightly by the G&A Module before plotting. After entering these parameters, the G&A Module will plot the data, either to the file specified, the screen or both. If the plot is to the screen, hitting RETURN will return the user to the command screen.

Table 15. List of Plotting Commands in Graph and Analyze Module

COMMAND	ARGUMENTS	DESCRIPTION
PLOT	[file name][VT240]	Plot the data set to the specified file name (*.TEK*) or to the screen [VT240 argument] (NOTE: Both arguments may be specified and the program will plot the data to the file and to the screen)
TITLE	[plot title]	Treat all following text as title for next plot, and center this text at the top of the plot
XLABEL	[x axis Label]	Treat all following text as the x axis label (up to 30 characters)
YLABEL	[y axis Label]	Treat all following text as the y axis label (up to 30 characters)
ZLABEL	[z axis Label]	Treat all following text as the z axis label (up to 30 characters)

The other commands shown in Table 15 provide a means for controlling the graphical presentation of the data. These commands include the TITLE command for placing a title at the top of the graph, and labeling commands for the x, y, and z axes: XLABEL, YLABEL, and ZLABEL, respectively. With all four of these commands, the text entered by the user following the command is treated as the title or axis label, respectively.

Table 16 lists the I/O and control commands of the G&A Module. There are currently five general control commands: WRITE, COSMETIC, NEW, EXIT, HELP, and REFRESH.

In order to conveniently store the x, y, and z data currently being plotted, SENTRAN7 provides a WRITE command in the G&A Module for writing the

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Table 16. List of I/O and Control Commands in Graph and Analyze Module

COMMAND	ARGUMENTS	DESCRIPTION
WRITE	[x, y, z file name]	Write the current data set to the named file as raw x, y, z data (default extension is *3D*)
COSMETIC	[file name]	Screendump of current G&A command screen to the named file
NEW	NONE	Restart the G&A Module
EXIT	NONE	Exit the G&A Module, return to Main Menu
HELP	[command name]	Accesses the G&A on-line help utility. If a valid G&A command is supplied as an argument, then help on the selected command is provided. If no argument is supplied, then a special introductory HELP screen is presented, listing all of the G&A commands.
REFRESH	NONE	Redraw the G&A command screen

data to a file. The user simply types 'write *filename*' at the command line prompt and the current x, y, and z data are written in three columns to that file. No header information is stored in the file. The filename is automatically given a *3D* extension if none is specified. For example, if the user enters 'write test', the data are written to the file *TEST.3D*. If the user enters 'write test.dat', the data are stored to the file *TEST.DAT*. These files can be used to save specific results the user is interested in, rather then saving the sometimes large *tape7* and *tape8* files that LOWTRAN7 and MODTRAN can produce. They can easily be plotted again at a later time by choosing the raw x, y, z plot type in the G&A Module. In addition, these data files can easily be used by other commercial graphics programs to create more detailed plots.

The COSMETIC command of the G&A Module provides a quick method for storing what data has been plotted or written to a raw x, y, z file. This command, writes a screendump of the G&A command screen to a file specified by the user. A default extension of *.COS* is attached to the filename if none is specified.

In order to restore altered data or to select an alternative data set, the user must restart the G&A Module by using the NEW command. This places the user at the initial G&A menu for choosing the plot type. The user will need to specify the plotting parameters again before resuming command mode. The NEW command must also be used to refresh the data set if, for example, the user wants to look at the derivative of the original data, after having already taken the LOG of the data.

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If for some reason the G&A command screen becomes corrupted (by a system message from another user, for example), the user can enter the REFRESH command to restore the G&A screen. This command simply redraws the command screen.

The HELP command accesses the G&A on-line help utility. This command is especially useful for recalling what commands are available within the G&A Module of SENTRAN7, and also what each of these commands do. If the user enters 'help' with no argument supplied, a special introductory help screen is presented, listing all the available G&A commands. The user can also obtain specific information about each of these commands by entering 'help *command*', where *command* is the command name the user needs a description of. For example, to obtain information about the PLOT command, the user enters 'help plot' at the command line. A help screen containing a description of the PLOT command will appear as shown in Figure 26. The user hits RETURN or ENTER to return to the G&A module command screen.

4.2.8.6   Viewing SENTRAN7 Plots on a Sun^{TM} Computer

As mentioned in Section 3.2, SENTRAN7 should be executed from the *xterm* Tektronix 4014 terminal emulator program on a Sun^{TM} computer. To view a SENTRAN7 plot, first follow the instructions to select a type of plot as described earlier in this section and the Tutorial (Section 5). To display a plot, type the SENTRAN7 command 'plot vt240' at the command line. After specifying the viewing angles, the plot will automatically appear in a Tektronix window. To get back to the SENTRAN7 command line, use the following procedure: Put the mouse in the Tektronix window, press the CTRL and Middle Mouse Buttons simultaneously. A Tektronix Options menu will then appear. Select the PAGE option to clear the window (otherwise subsequent plots will be overlayed) and then select the Hide Tek Window Option. After the Tektronix window dissappears, move the cursor to the Xterm window and hit RETURN to get to the command line.

4.2.9   Plotting Trace Gas Input Profiles

A feature of SENTRAN7 is the ability to plot trace gas profiles and their perturbations. This option has been implemented in a two-step process. The user first stores the trace gas profile, and its perturbation values, if any, by typing the command 'write' when editing the particular molecular species on Card 2C. Second, the user plots these data from within the G&A Module of SENTRAN7 by choosing the option to plot a raw x, y, z data file and entering the filename created within the Edit Module.

When the user types 'write' while editing Card 2C, the input profile data for

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SENTRAN7 GRAPHICS & ANALYSIS MODULE

PLOT TYPE: TRANSMITTANCE   FILE NAME : TAPE7.OUT

X-AXIS   : WAVENUMBER

Y-AXIS   : RANGE

UNITS

Z-AXI

COMM

SENTRAN HELP UTILITY

The PLOT command initiates the plotting sequence. PLOT requires
at least one argument. The argument will generally be a .TEK
output file. However, the name VT240 is a reserved argument
which will send graphical output to the terminal. An output
file name and the VT240 argument can both be provided, causing
output to be directed to the screen and the .TEK file simultaneously.

EXAMPLE :

PLOT TEST VT240

Will form a graphics file TEST.TEK and display the plot on the user's
terminal. After the PLOT command is entered, the user is prompted for
rotation angles. PLOT then proceeds and returns to COMMAND input when
finished.

HIT <RETURN> TO CONTINUE

Figure 26. On-Line Help Screen Within Graph and Analyze Module of SEN-
TRAN7. Note that the help screen does not appear as a partial overlay during
execution as shown in this figure, but rather covers the entire screen

the molecular species the user is currently editing is written to a raw data file.
If the molecular species has been perturbed by the user, the perturbation values
are also written to the data file. The data files are automatically named by the
program with the first part of the filename being set to the parameter name (i.e.,
P, T, O3, etc.), and the default extension .3D used. The data file consists of five
columns. The first column consists of the data values for the unperturbed molecular
species. The second column, which represents the y axis data, will always be zero
because this is a 2D plot. The third column contains the altitude data to be plotted
on the z axis. The fourth and fifth columns contain the minus and plus percent
perturbations, respectively, of the original molecular s   s data values. If no
percent perturbation was entered by the user, these colunms are set to −999.0.

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At this point, it must be mentioned that the 'write' command creates a .3D data file based on numerical values in the specified .PRO file, but it does not consider the values of JCHAR. This is an important footnote to remember because MODTRAN uses model atmosphere amounts for layers where JCHAR is set to 1-6, even if numerical values are specified. For these scenarios, the trace gas profiles plotted by SENTRAN7 do not represent the actual profiles used by MODTRAN. Also, the 'write' command is not allowed when the user has selected random perturbations (i.e., the 'ran1' and 'ran2' commands) for an atmospheric variable. Instead, SENTRAN7 creates the fixed files named RANDOM1.DAT and RANDOM2.DAT as discussed in Section 4.2.3.

Figures 27-31 provide the user with a specific example of how to perturb a parameter on Card 2C and write the input profile of this parameter, along with its perturbation values, to a file. This example perturbs the O_3 parameter on Card 2C by 20% and writes the input profile to the default file, O3.3D. The user is editing Card 2C and presses RETURN until the cursor is positioned on the line containing the O3 parameter. The user then enters '%20' for the perturbation value for the O_3 parameter, as shown in Figure 27, and hits RETURN. The cursor is now located on the N_2O parameter on Card 2C. To move the cursor back to the O_3 parameter, the user enters the 'up' command, as shown in Figure 28. The 'up' command moves the cursor back to the line containing the O_3 parameter. The user then types in 'write' while on the line containing the O_3 parameter in order to write the O_3 input profile and its perturbation values to the file O3.3D. This is shown in Figure 29. Once the file has been written, the name of the file is displayed in the lower right hand corner of the screen, as shown in Figure 30. The contents of the file O3.3D are shown in Figure 31. Recall that the first column is the original O_3 input profile and the third column is the altitude. The fourth column is a -20% perturbation and the fifth column is a 20% perturbation of the first column.

Note that the above example was a specific example involving the O_3 parameter on Card 2C. The user can perturb any of the parameters on Card 2C and write that parameter's input profile and perturbation values to a file, using a similar method. Also note that it is not necessary to perturb the input profile before writing that profile to an output file. If the user wishes to write the input profile of a parameter on Card 2C to a file, without perturbing that parameter, the user simply enters the 'write' command when the cursor is located at the desired parameter, without having entered any percent perturbation.

Once the input profiles on Card 2C have been written to an output file, they can be plotted within the G&A Module by choosing the raw x, y, z plot type and entering the output filename (*.3D) saved within the Edit Module. The graphical output of the O_3 input profile saved in the example above, is shown in Figure 32. The O_3 input profile is plotted along with ±20% perturbations. This plot is created

Figure 27. Example of the Command to Perturb the O_3 Input Profile in Card 2C by 20%

Figure 28. Example of the Command to Move the Cursor Up One Line to the O_3 Parameter on Card 2C

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Figure 29. Example of the Command to Write the O_3 Input Profile in Card 2C to a Data File

Figure 30. Example of the Screen Displayed After the O_3 Input Profile Has Been Written to a File

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0.02869	0.00000	0.00000	0.02295	0.03443
0.03150	0.00000	1.00000	0.02520	0.03780
0.03342	0.00000	2.00000	0.02674	0.04010
0.03504	0.00000	3.00000	0.02803	0.04205
0.03561	0.00000	4.00000	0.02849	0.04273
0.03767	0.00000	5.00000	0.03014	0.04520
0.03989	0.00000	6.00000	0.03191	0.04787
0.04223	0.00000	7.00000	0.03378	0.05068
0.04471	0.00000	8.00000	0.03577	0.05365
0.05000	0.00000	9.00000	0.04000	0.06000
0.05595	0.00000	10.00000	0.04476	0.06714
0.06613	0.00000	11.00000	0.05290	0.07936
0.07815	0.00000	12.00000	0.06252	0.09378
0.09289	0.00000	13.00000	0.07431	0.11147
0.10500	0.00000	14.00000	0.08400	0.12600
0.12560	0.00000	15.00000	0.10048	0.15072
0.14440	0.00000	16.00000	0.11552	0.17328
0.25000	0.00000	17.00000	0.20000	0.30000
0.50000	0.00000	18.00000	0.40000	0.60000
0.95000	0.00000	19.00000	0.76000	1.14000
1.40000	0.00000	20.00000	1.12000	1.68000
1.80000	0.00000	21.00000	1.44000	2.16000
2.40000	0.00000	22.00000	1.92000	2.88000
3.40000	0.00000	23.00000	2.72000	4.08000
4.30000	0.00000	24.00000	3.44000	5.16000
5.40000	0.00000	25.00000	4.32000	6.48000
9.30000	0.00000	30.00000	7.44000	11.16000
9.70000	0.00000	35.00000	7.76000	11.64000
7.50000	0.00000	40.00000	6.00000	9.00000
4.50000	0.00000	45.00000	3.60000	5.40000
2.80000	0.00000	50.00000	2.24000	3.36000
0.30000	0.00000	70.00000	0.24000	0.36000
0.40000	0.00000	100.00000	0.32000	0.48000

Figure 31. Sample Trace Gas Input Profile Data File (O3.3D) That Is Produced for Plotting by the G&A Module

by choosing the raw x, y, z plot type within the G&A Module and entering the filename O3.3D. The user must label the axes by using the XLABEL and ZLABEL commands before plotting the data. The LOG command within the G&A Module can also be used on the input profile plots. However, the derivative commands are not available when plotting trace gas input profiles.

4.2.10 View File Module

A new feature in SENTRAN7 is a general View File Module in the Main Menu. This feature can speed up a sensitivity analysis because users are able to examine files generated by SENTRAN7 without leaving the program (such as SEN.LOG or TAPE7.OUT.

To view a file, enter '9' or 'view' at the Main Menu command line. SENTRAN7 will then prompt the user for the file to be listed, as shown in Figure 33. Note that the user must enter both the name and extension of the desired file. If the

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```
X : OZONE        0.2295E-01 TO  1.1640E+01 (TICK=   1.1)
Z : ALTITUDE     0.0000E+00 TO  1.0000E+02 (TICK=   5.0)
```
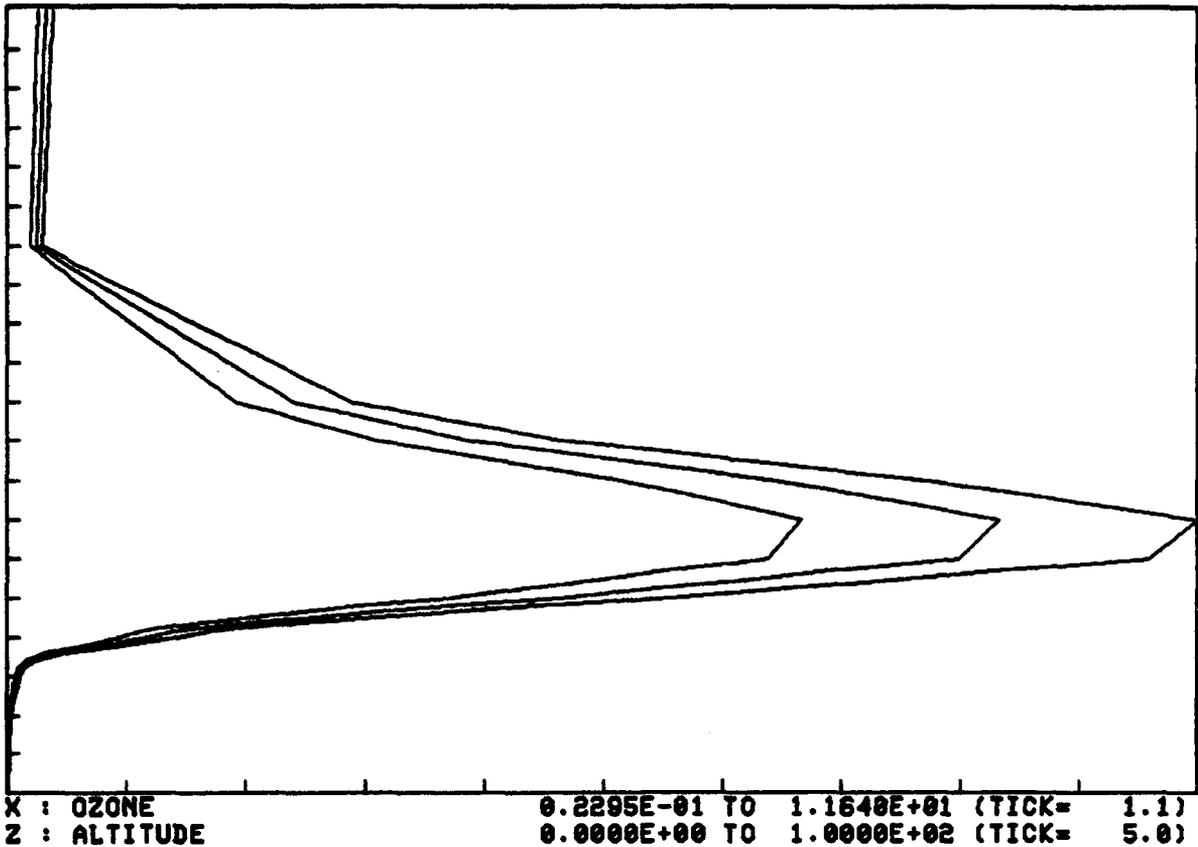
Figure 32. Example of a 2D Plot of O_3 Input Profile with ± 20% Perturbations

specified file exists, SENTRAN7 will list the file as shown in Figure 34. Note that the program contains a scrolling feature so that for long files, the user will be required to hit RETURN several times. If the specified file does not exist, the program will give a list of all files in the current directory, as shown in Figure 35. Note that SENTRAN7 allows a user to save several steps by specifying the file name to be viewed from the Main Menu prompt. Typing 'view model1.pro' or 'v model1.pro' from the Main Main, for example, will instruct SENTRAN7 to list the file *MODEL1.PRO*.

It is worth mentioning that View File Module converts all file names to upper case, so it cannot be used to view files on Unix systems that contain lower case letters, such as *Makefile*. Also, any text beyond Column 80 is not shown when the file is listed.

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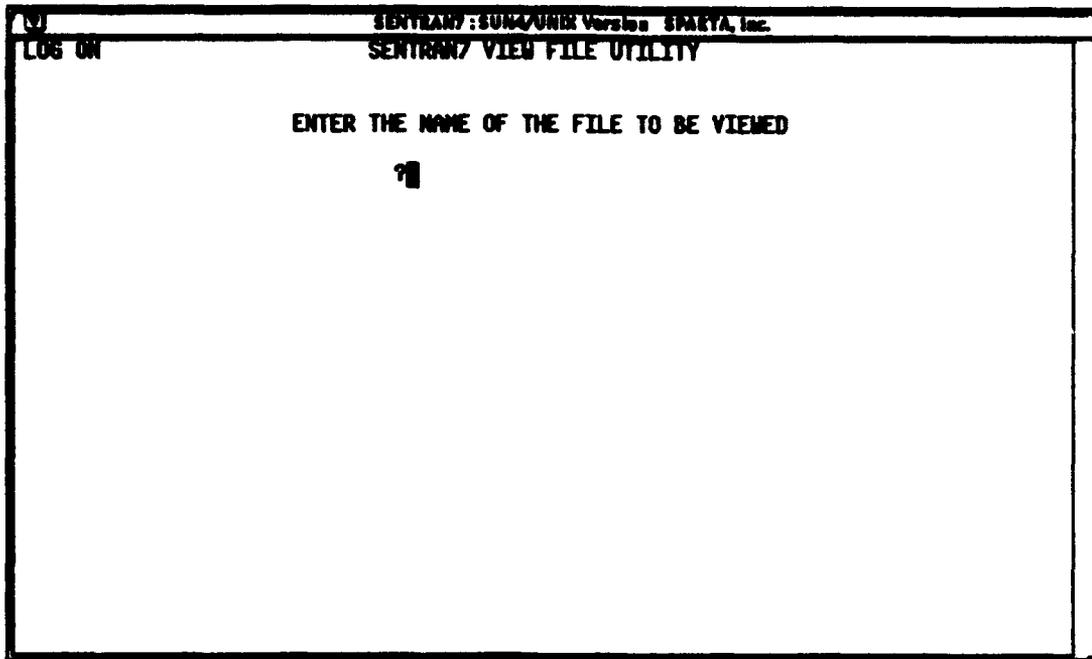
Figure 33. Prompt Displayed in the View File Module to Enter the File Name To Be Viewed
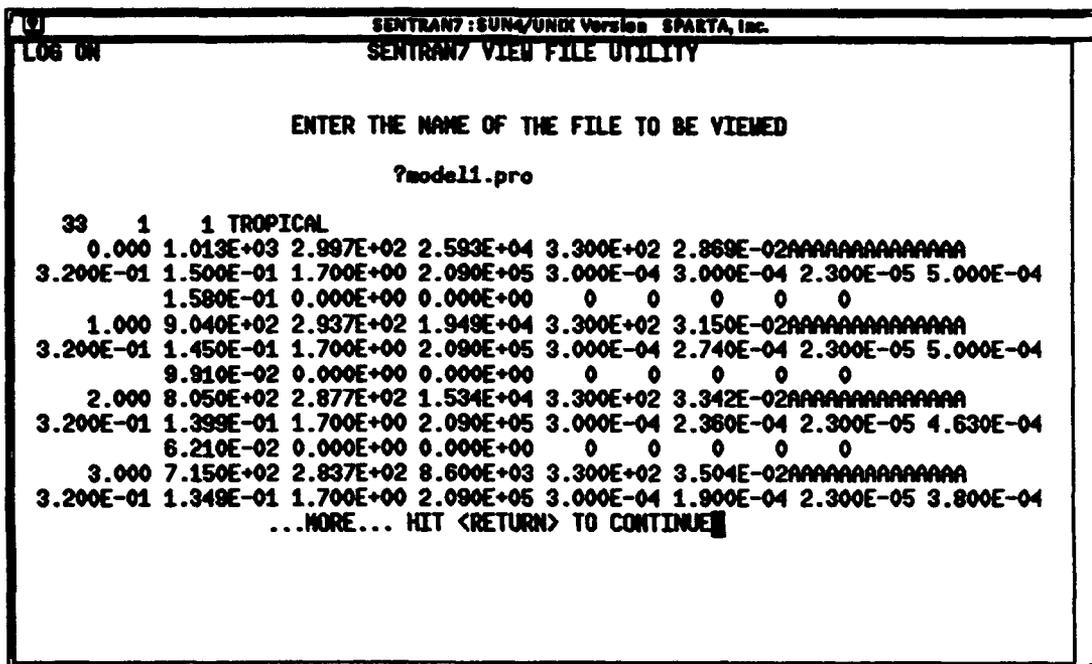
Figure 34. Example of a File Listing in the View File Module. A scrolling feature is used when the file is more than a few lines

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```
┌─────────────────────────────────────────────────────────────┐
│ ▣                 SENTRAN7:SUN/UNIX Version  SMETA,Inc.       │
│        CHOOSE ONE OF THE FOLLOWING. HIT <ENTER> TO ESCAPE.    │
│                            *.*                                │
│  DIRECT.ORY     SEN.LOG      defpert.ps    ihal.rs    tutoridx.eps  │
│  LAST.MTH       TAPE7.OUT    defran.ps     logon.ps   tutorit2a.eps │
│  MAJMBS.DAT     TAPE9.OUT    detpfinl.ps   makevug.tex vufile.rs    │
│  MODEL1.PRO     TEST.INP     detpmenu.ps   menus.tex  vufile2.rs    │
│  MODEL2.PRO     TEST.MTH     dodetp.ps     renfinl.ps vuproa.rs     │
│  MODEL3.PRO     TEST.TP6     doran.ps      renmenu.ps               │
│  MODEL4.PRO     TEST.TP7     errpro1.ps    runinfo.rs              │
│  MODEL5.PRO     TEST.TP8     errpro2.ps    runinp.rs               │
│  MODEL6.PRO     defdetp.ps   graphs.tex    tutor1.eps             │
│                                                              │
│                                                              │
│                                                              │
│  FILE NAME :  ▋                                               │
│                                                              │
│  FILE NOT FOUND: ASDASD                                       │
│                                                              │
└─────────────────────────────────────────────────────────────┘
```

Figure 35. Directory Listing in the View File Module After Users Try to View a File That Does Not Exist

4.2.11 Miscellaneous

There are four additional commands that can be issued from the Main Menu, although they are not displayed as Main Menu choices. These commands are LOG, ABS, NOPROMPT, and ZAP. Note that these commands should be entered in their entirety.

4.2.11.1 LOG Command

The LOG command controls SENTRAN7's logging capability. When the log is active, SENTRAN7 will write all user input to a file named *SEN.LOG*. This file also contains comments supplied by SENTRAN7 that help users to determine the logical flow taken through SENTRAN7, develop sensistivity studies interactively, and debug files for batch submission. Users may replace these automatic comments with comments of their own when entering commands into SENTRAN7. Comments consist of all text within the input string following an apostrophe. When users type **edit 'invoke editor function**, for example, "invoke editor function" is a comment that will be ignored by the program, but it will appear in *SEN.LOG*.

Upon entering the code, SENTRAN7 activates the log file feature as its default execution mode. The word LOG appears in the extreme upper left of all SENTRAN7 menus when the LOG feature is active as shown in Figure 36. The LOG command functions as a toggle. Therefore, if users do not want this feature, it can be deactived by typing 'log'.

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Note that information on all actions are continuously written to the *SEN.LOG* file until the user closes it or until the users exits SENTRAN7. Thus, the *SEN.LOG* file can be come quite large during long SENTRAN7 sessions or when the SENTRAN7 error checking package (see Section 4.3) has identified many compilation errors. Therefore, it is recommended that users close and reopen the *SEN.LOG* file occasionally by entering 'log' twice from the Main Menu.

```
┌──────────────────────────────────────────────────────────────────┐
│(U)            SENTRAN7 : SUN4/UNIX Version   SPARTA, Inc.         │
│LOG ON                  WELCOME TO SENTRAN7                        │
│         THE SENSITIVITY ANALYSIS PROGRAM FOR LOWTRAN7/MODTRAN     │
│                                                                    │
│                     1 - LOAD/SAVE                                 │
│                                                                    │
│                     2 - DEFINE PERTURBATIONS                      │
│                                                                    │
│                     3 - EDIT                                      │
│                                                                    │
│                     4 - COMPILE                                   │
│                                                                    │
│                     5 - SELECT LOWTRAN7/MODTRAN                   │
│                                                                    │
│                     6 - RUN MODTRAN                               │
│                                                                    │
│                     7 - GRAPH & ANALYZE                           │
│                                                                    │
│                     8 - HELP                                      │
│                                                                    │
│                     9 - VIEW FILE                                 │
│                     10 - QUIT                                     │
│?█                                                                 │
└──────────────────────────────────────────────────────────────────┘
```

Figure 36. Example of the Main Menu Display When the Log File Is Active. The word LOG appears in the extreme upper left of all SENTRAN7 menus when the LOG feature is active

4.2.11.2 ABS Command

SENTRAN7 permits users to deactivate the listing of active molecular absorbers in the Compile Module. This feature has been added to SENTRAN7 to speed up sensitivity studies that involve wavelength regions with many molecular absorption bands. That is, the process of listing all molecular absorbers can be time consuming, requiring the user to hit RETURN many times.

To deactivate the listing of active molecular absorbers, type 'abs' from the Main Menu. SENTRAN7 will modify the Main Menu as shown in Figure 37. The ABS command functions as a toggle. Therefore, if the user wants to restart the listing of molecular absorbers, type 'abs' a second time.

```
┌─────────────────────────────────────────────────────────────────┐
│ ⊞                    SENTRAN7 : SUN4/UNIX Version  SPARTA, Inc.    │
│ LOG ON                    WELCOME TO SENTRAN7                      │
│           THE SENSITIVITY ANALYSIS PROGRAM FOR LOWTRAN7/MODTRAN    │
│                                                                   │
│                        1 - LOAD/SAVE                              │
│                                                                   │
│                        2 - DEFINE PERTURBATIONS                   │
│                                                                   │
│                        3 - EDIT                                   │
│                                                                   │
│                        4 - COMPILE W/O ABSORBER LIST              │
│                                                                   │
│                        5 - SELECT LOWTRAN7/MODTRAN               │
│                                                                   │
│                        6 - RUN LOWTRAN7                          │
│                                                                   │
│                        7 - GRAPH & ANALYZE                       │
│                                                                   │
│                        8 - HELP                                  │
│                                                                   │
│                        9 - VIEW FILE                             │
│                                                                   │
│                       10 - QUIT                                  │
│  ?▌                                                              │
│                                                                   │
└─────────────────────────────────────────────────────────────────┘
```

Figure 37. Example of the Main Menu Display After the Listing of the Activate Molecular Absorbers Has Been Turned Off. Note that the Compile Module descriptor has been modified.

4.2.11.3 NOPROMPT Command

The NOPROMPT command suppresses all writing to the screen. This feature is useful for batch submissions because screen output is unnecessary in such situations.

The NOPROMPT command functions as a toggle. Therefore, if screen output is inadvertently disabled, it can be reactived by typing 'noprompt' a second time.

4.2.11.4 ZAP Command

The ZAP command resets all LOWTRAN7 and MODTRAN variables to their default values and eliminates all perturbation directives. (The default values are "hardwired" into the SENTRAN7 code and cannot be changed.) The ZAP command can be useful when the user wishes to make extensive revisions to the sensitivity problem currently defined within the Edit mdule. That is, it is often quicker to start from the default values for the LOWTRAN7 and MODTRAN variables, with no perturbations, rather than manually resetting all the variables that already have perturbations associated with them.

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4.3 Error Checking Package

4.3.1 Implementation

The SENTRAN7 error checking package operates on problems having a user-defined atmosphere and/or aerosol wavelength scaling factors. These classes of problems require MODEL=7 on Card 1 and/or IHAZE=7 or ICLD=11 on Card 2. Also, the user must verify that the SENTRAN7's log file is activated because the SENTRAN7 error checking package writes its detailed information to the log file. The log file is active when the LOG message appears in the top left hand corner of the SENTRAN7 menus (see Figure 36, for example). If the message does not appear, type 'log' from the Main Menu. Note that SENTRAN7 activates the log file feature as its default execution mode.

The SENTRAN7 error checking package automatically executes in two places:

1. In the Edit Module, immediately after the user specifies either a .PRO or a .AER file

2. In the Compile Module, as SENTRAN7 creates the LOWTRAN7 and MOD-TRAN card images.

The second error check is required in order to check perturbed values. Also, the error checking in the Edit Module is performed only after SENTRAN7 has successfully read the specified .PRO or .AER file. If SENTRAN7 cannot successfully read a .PRO or .AER file, an error message is displayed on the screen, but no detailed information is written to SEN.LOG.

4.3.2 First Example of the Error Checking Package

In order to demonstrate the SENTRAN7's error checking package, a profile file named ERRCHK.PRO was developed from the Midlatitude Summer atmosphere (i.e., the MODEL2.PRO file) and three errors were intentionally introduced:

1. The second layer pressure was changed from 902.0 mb to 90.2 mb

2. The third layer temperature was changed from 285.2 K to 385.2 K

3. The fourth layer value of JCHAR for ozone was set to "O".

The ERRCHK.PRO was then accessed in the Edit Module by opting for a user-defined atmosphere (MODEL=7 on Card 1) and entering 'errchk' as the .PRO file to be used. After reading the ERRCHK.PRO file, the SENTRAN7 error checking package issued messages that it found two Major errors and two Warnings as shown in Figure 38 and Figure 39, respectively. The detailed information written to the SEN.LOG file is shown in Figure 40. As Figure 40 indicates, the SENTRAN7 error checking package successfully detected the Major errors and Warning conditions in the ERRCHK.PRO file.

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```
┌─────────────────────────────────────────────────────────┐
│ ⊡          SENTRAN7:SUN4/UNIX Version  SPARTA, Inc.       │
│                SENTRAN7 EDITING UTILITY                   │
│                                                           │
│                 READING INFO FOR CARD 2C                  │
│                                                           │
│ FILENAME FOR MINOR AND TRACE GAS PROFILES [.PRO] ? ERRCHK.PRO │
│                                                           │
│                                                           │
│                                                           │
│          2 MAJOR ERROR(S) IN MINOR AND TRACE GAS FILE !   │
│                                                           │
│   DETAILS IN LOG FILE. MAJOR ERRORS SHOULD BE FIXED BEFORE PROCEEDING. │
│                                                           │
│                 PRESS <RETURN> TO CONTINUE█               │
│                                                           │
│                                                           │
│                                                           │
│                                                           │
│                                                           │
└─────────────────────────────────────────────────────────┘
```

Figure 38. Example of a Message Displayed in the Edit Module To Inform the User That Major Errors Were Detected. Similar messages are issued from the Compile Module

```
┌─────────────────────────────────────────────────────────┐
│ ⊡          SENTRAN7:SUN4/UNIX Version  SPARTA, Inc.       │
│                SENTRAN7 EDITING UTILITY                   │
│                                                           │
│                 READING INFO FOR CARD 2C                  │
│                                                           │
│ FILENAME FOR MINOR AND TRACE GAS PROFILES [.PRO] ? ERRCHK.PRO │
│                                                           │
│                                                           │
│                                                           │
│         2 WARNING(S) IN MINOR AND TRACE GAS PROFILES !    │
│                                                           │
│   DETAILS IN LOG FILE. WARNINGS SHOULD BE REVIEWED BEFORE PROCEEDING. │
│                                                           │
│                PRESS <RETURN> TO CONTINUE    █            │
│                                                           │
│                                                           │
│                                                           │
│                                                           │
│                                                           │
└─────────────────────────────────────────────────────────┘
```

Figure 39. Example of a Message Given in the Edit Module To Inform the User That Warning Conditions Were Detected. Similar messages are issued from the Compile Module

```
3
pd                                              'MODEL
                                                'CARD 1  O.K. ?
pd                                              'IHAZE
                                                'CARD 2  O.K. ?
errchk                                          'TRACE GAS FILENAME
                               EDIT MODULE ERROR CHECKING FOR CARD 2C PROFILES
                                        MAJOR ERROR DISCOVERED IN P PROFILE
SUSPECT LAYER NUMBER  3.  REASON: PRESSURES DO NOT DECREASE MONOTONICALLY
                                     MAJOR ERROR DISCOVERED IN TRACE GAS PROFILE
SUSPECT LAYER NUMBER  4.  REASON: BAD VALUE OF JCHAR FOR O3
                                                'TRACE GAS FILE ERROR
                               EDIT MODULE WARNINGS FOR CARD 2C PROFILES
                                        WARNING MESSAGE FOR P PROFILE
SUSPECT LAYER NUMBER  2.  REASON: PRESSURE IS OUT OF REASONABLE BOUNDS
                                        WARNING MESSAGE FOR T PROFILE
SUSPECT LAYER NUMBER  3.  REASON: TEMPERATURE IS OUT OF REASONABLE BOUNDS
                                                'TRACE GAS FILE WARNING
end                                             'ZMDL
9
```

Figure 40. Example of the Information Sent to the *SEN.LOG* File from the SEN-TRAN7 Error Checking Package After Accessing An Atmospheric Profile File That Contained Errors in the Pressure, Temperature, and Ozone Profiles

4.3.3   Second Example of the Error Checking Package

This example accesses the SENTRAN7 error checking package from the Compile Module. Here, a user-defined atmosphere (MODEL=7 on Card 1) was specified and the US Standard Atmosphere (*MODEL6.PRO*) was selected as the *.PRO* file to be used in this example. As for perturbations, all layer pressures and temperatures were perturbed by 10%. After entering the Compile Module, the command 'err2 /n' was issued to compile the problem as NOMESH and create the input file named *ERR2.INP*. During compilation, the SENTRAN7 error checking package issued a message similar to that in Figure 38 saying that it had detected twelve Major errors. The detailed information written to the *SEN.LOG* file is shown in Figure 41. As Figure 41 indicates, the Major errors were discovered during compilation because certain combinations of pressure and temperature perturbations lead to humidities greater than 100%, even though the *.PRO* file is okay.

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```
4
test/nomesh                              'FILE NAME FOR INPUT DECK

                    COMPILE MODULE ERROR CHECKING FOR CARD 2C PROFILES
                                        NO COMPILATION ERRORS FOUND
                        COMPILE MODULE WARNINGS FOR CARD 2C PROFILES
                                        NO WARNINGS FOUND
                    COMPILE MODULE ERROR CHECKING FOR CARD 2C PROFILES
                                        NO COMPILATION ERRORS FOUND
                        COMPILE MODULE WARNINGS FOR CARD 2C PROFILES
                                        NO WARNINGS FOUND
                    COMPILE MODULE ERROR CHECKING FOR CARD 2C PROFILES
                                MAJOR ERROR DISCOVERED IN H2O PROFILE
SUSPECT LAYER NUMBER  1.  REASON: RELATIVE HUMIDITY EXCEEDS 100%
                                MAJOR ERROR DISCOVERED IN H2O PROFILE
SUSPECT LAYER NUMBER  2.  REASON: RELATIVE HUMIDITY EXCEEDS 100%
                                MAJOR ERROR DISCOVERED IN H2O PROFILE
SUSPECT LAYER NUMBER  3.  REASON: RELATIVE HUMIDITY EXCEEDS 100%
                                MAJOR ERROR DISCOVERED IN H2O PROFILE
SUSPECT LAYER NUMBER  4.  REASON: RELATIVE HUMIDITY EXCEEDS 100%
                                MAJOR ERROR DISCOVERED IN H2O PROFILE
SUSPECT LAYER NUMBER  5.  REASON: RELATIVE HUMIDITY EXCEEDS 100%
                                MAJOR ERROR DISCOVERED IN H2O PROFILE
SUSPECT LAYER NUMBER  6.  REASON: RELATIVE HUMIDITY EXCEEDS 100%
                                MAJOR ERROR DISCOVERED IN H2O PROFILE
SUSPECT LAYER NUMBER  7.  REASON: RELATIVE HUMIDITY EXCEEDS 100%
                                MAJOR ERROR DISCOVERED IN H2O PROFILE
SUSPECT LAYER NUMBER  8.  REASON: RELATIVE HUMIDITY EXCEEDS 100%
                                MAJOR ERROR DISCOVERED IN H2O PROFILE
SUSPECT LAYER NUMBER  9.  REASON: RELATIVE HUMIDITY EXCEEDS 100%
                                MAJOR ERROR DISCOVERED IN H2O PROFILE
SUSPECT LAYER NUMBER 10.  REASON: RELATIVE HUMIDITY EXCEEDS 100%
                                MAJOR ERROR DISCOVERED IN H2O PROFILE
SUSPECT LAYER NUMBER 11.  REASON: RELATIVE HUMIDITY EXCEEDS 100%
                                MAJOR ERROR DISCOVERED IN H2O PROFILE
SUSPECT LAYER NUMBER 12.  REASON: RELATIVE HUMIDITY EXCEEDS 100%
                                    'TRACE GAS COMPILATION ERROR
                        COMPILE MODULE WARNINGS FOR CARD 2C PROFILES
                                        NO WARNINGS FOUND
                    COMPILE MODULE ERROR CHECKING FOR CARD 2C PROFILES
                                        NO COMPILATION ERRORS FOUND
                        COMPILE MODULE WARNINGS FOR CARD 2C PROFILES
                                        NO WARNINGS FOUND
                    COMPILE MODULE ERROR CHECKING FOR CARD 2C PROFILES
                                        NO COMPILATION ERRORS FOUND
                        COMPILE MODULE WARNINGS FOR CARD 2C PROFILES
                                        NO WARNINGS FOUND
                            'PRESS <RETURN> TO CONTINUE
9
```

Figure 41. Example of the Information Sent to the *SEN.LOG* File from the SEN-TRAN7 Error Checking Package After Attempting to Compile A Problem In Which Layer Pressures and Temperatures Are Perturbed

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5 SENTRAN7 TUTORIALS

While the previous chapters provided a fairly general description of SEN-TRAN7 from a functional point of view, it does little in the way of teaching the user to actually use SENTRAN7. The following chapter of this report will guide the user through a series of brief exercises which should make the user reasonably comfortable with using SENTRAN7. It is encouraged that the user actually use the program while proceeding through these tutorials.

5.1 Basic Concepts of the User Interface

One of the chief features of SENTRAN7 is its flexible user interface, which permits users to perform the exact same task in a number of different ways. This allows the program to accommodate differences in personal preference with respect to data entry and makes it more comfortable for users who have differing levels of skill in using the program. For example, novice users can proceed in a step-by-step manner, providing simple responses to a series of prompts, while advanced users may prefer to type in complete command strings, bypassing the majority of input prompts. This command parsing feature can dramatically reduce the time required to perform routine tasks. The following tutorials will demonstrate both step-by-step and command driven syntax. Again, we stress that it is worth the time investment required to use the software while learning the command driven syntax.

5.2 Conventions Used in the Tutorials

As the user proceeds through the following tutorials, please keep the following conventions in mind:

- The text which must be entered will appear in '**boldface**', and single quotes. Note also that when running SENTRAN7 you may use either lower or upper case.
- You must press the RETURN or ENTER key after every command.
- Often, the only input required will be the pressing of the RETURN key (*i.e.*, when accepting a default, or acknowledging an error message). Therefore RETURN means "press the return or enter key". Note that the term "RETURN key" is equivalent to "ENTER key" in these tutorials.

5.3 SENTRAN7 Tutorial #1

5.3.1 Getting Started

Begin by executing the SENTRAN7 executable file on your system. The file, *LAST.MTH*, is loaded into SENTRAN7 immediately upon execution, provided that it exists, and provides a default methodology. A methodology file, such as *LAST.MTH*, contains images of LOWTRAN7 or MODTRAN input parameters (the standard input "cards") and control parameters for their perturbation. When running SENTRAN7, the most recent methodology file generated is always copied into a special file named *LAST.MTH*, which as mentioned above is used by SENTRAN7 at start-up. When SENTRAN7 is executed for the first time, a *LAST.MTH* methodology file may not yet exist. If this is the case the initial screen will look like Figure 42. The program displays an error message in reading the last methodology file. Don't panic! The program will continue with the default parameters set within the software code. Once you hit RETURN, the SENTRAN7 Main Menu will appear, as shown in Figure 43.

5.3.2 Using the Load and Save Module

The Load and Save Module permits you to retrieve and store LOWTRAN7 and MODTRAN input parameters and directives for parameter variation. In the following tutorial, we will load one of the methodology files that is supplied with your distribution tape named *DEFAULT.MTH*, and save it under the name *FIRST.MTH*, using both step-by-step and command driven techniques.

1) Type '1' at the Main Menu shown in Figure 43 in order to load a methodology file.

2) SENTRAN7 will prompt you to specify if you want to load or save a methodology file, as shown in Figure 44. In response to this prompt, enter 'load'.

The program will then display a list of all the files in the current directory that have the extension *.MTH*, which is the default extension for methodology files, and will prompt you for the file name to load. An example screen is shown in Figure 45. Note that your screen will not look exactly like this example because you will not have the same methodology files in your current directory.

3) In response to the prompt for a methodology file name, enter 'default'. SENTRAN7 will load *DEFAULT.MTH* and return to the Main Menu.

4) Now, repeat Step 1 and type 'load default' at Step 2. Note that this accomplishes the same task as Steps 1, 2 and 3 in one less step.

5) Now, at the Main Menu type 'load default'. Note that we have accomplished the task of loading *DEFAULT.MTH* in a single step!

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ERROR READING METHODOLOGY FILE

PRESS <RETURN> TO CONTINUE
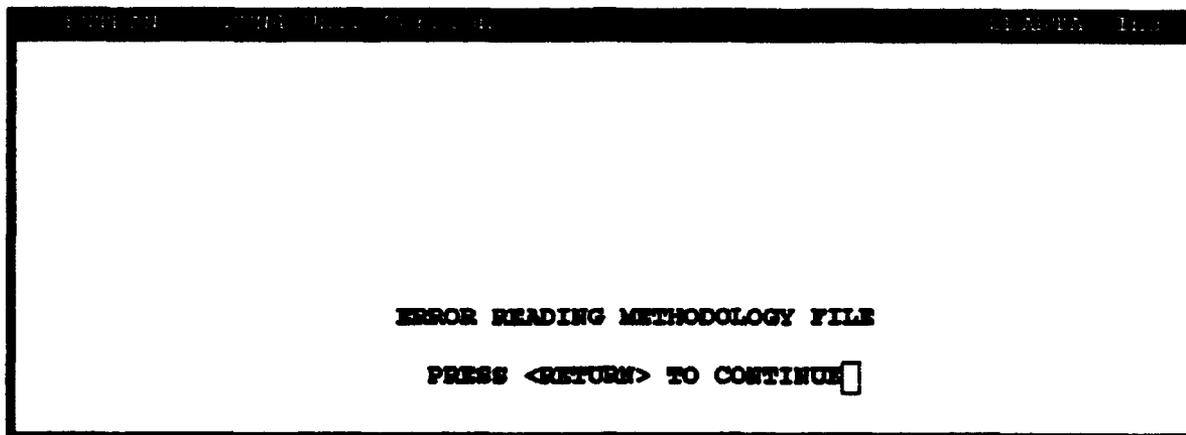
Figure 42. SENTRAN7 Initial Screen Displayed When the *LAST.MTH* Methodology File Does Not Exist

SENTRAN7: SUN4/UNIX Version   SPARTA, Inc.

LOG ON   WELCOME TO SENTRAN7
        THE SENSITIVITY ANALYSIS PROGRAM FOR LOWTRAN7/MODTRAN

                    1 - LOAD/SAVE

                    2 - DEFINE PERTURBATIONS

                    3 - EDIT

                    4 - COMPILE

                    5 - SELECT LOWTRAN7/MODTRAN

                    6 - RUN MODTRAN

                    7 - GRAPH & ANALYZE

                    8 - HELP

                    9 - VIEW FILE

                   10 - QUIT

?
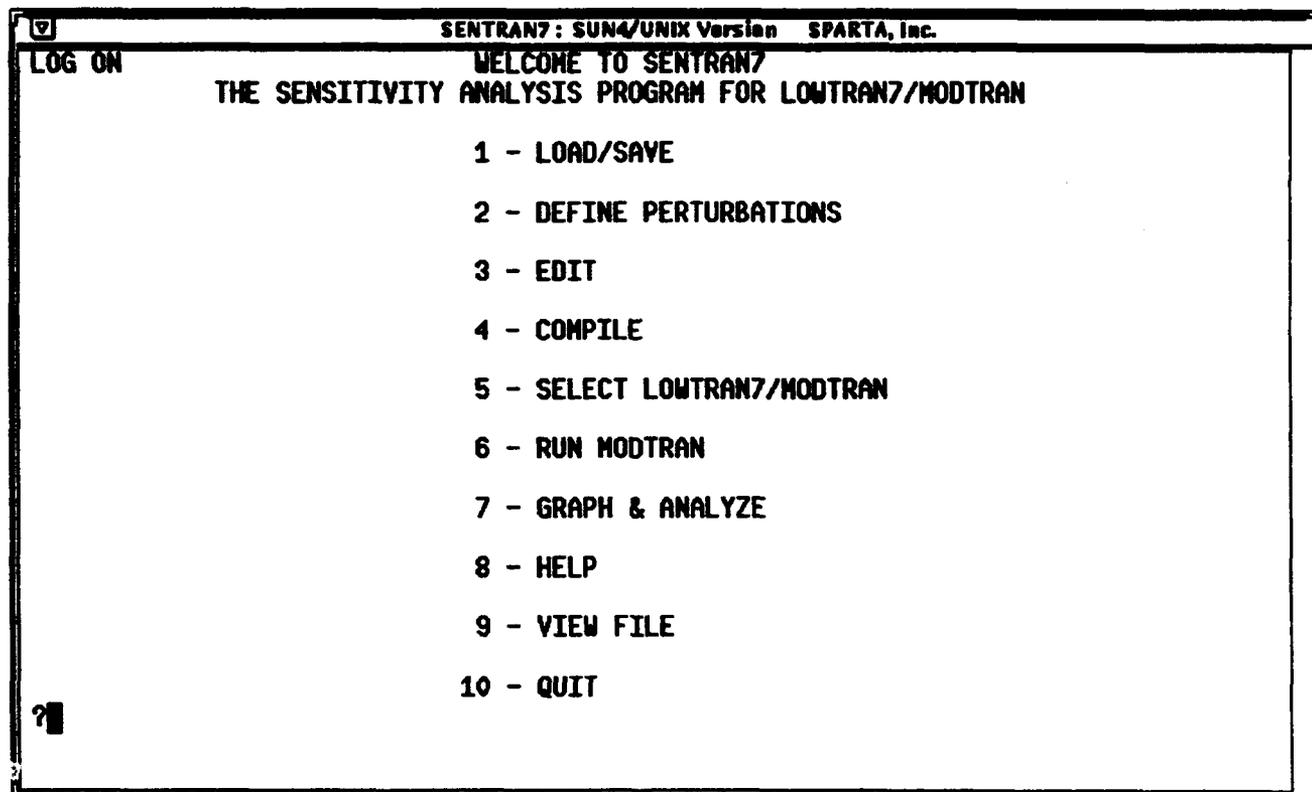
Figure 43. Main Menu of SENTRAN7

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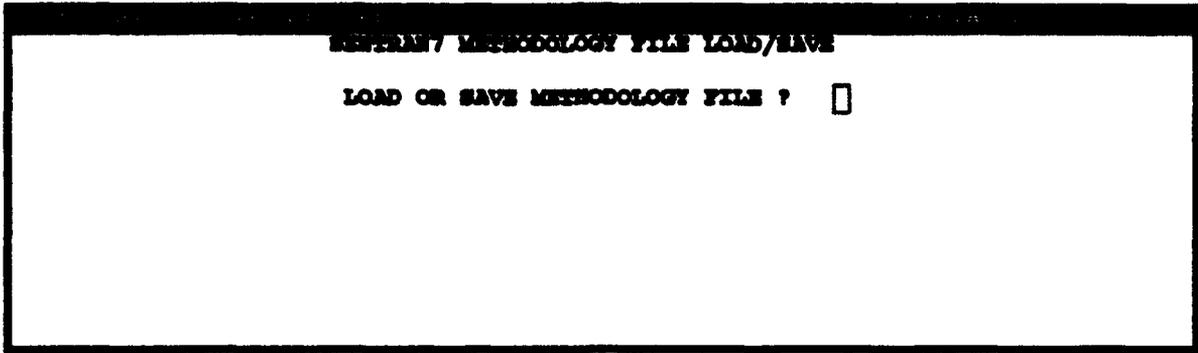
Figure 44. Screen Prompt for Specifying Use of the Load or Save Options
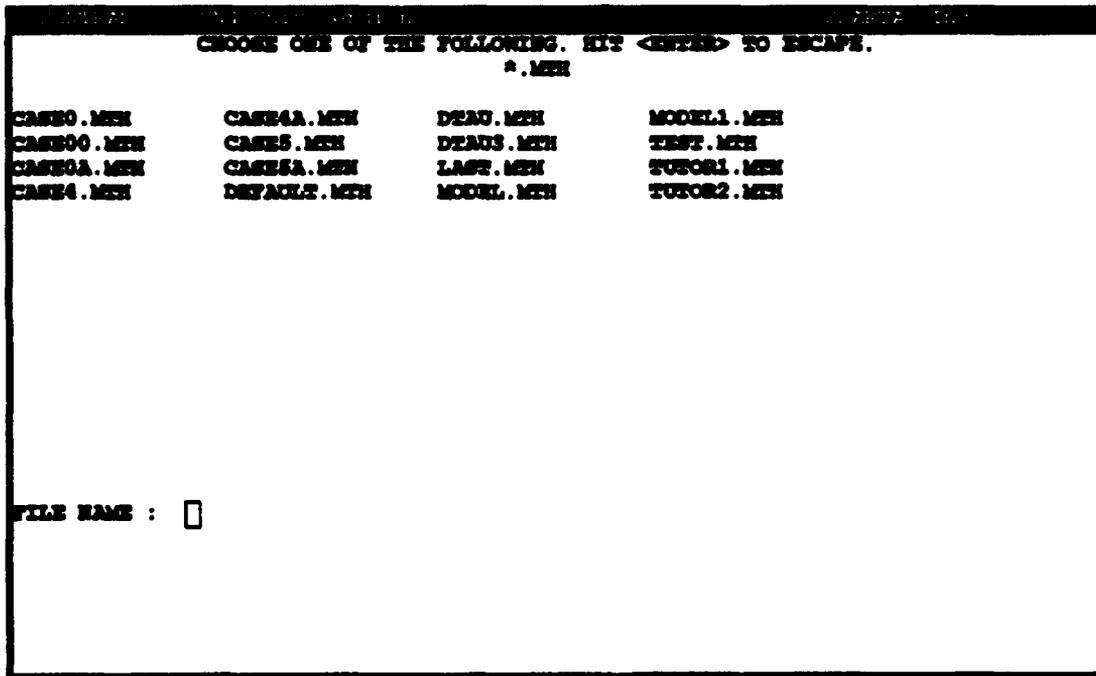
Figure 45. Example of a Screen Listing of the Available Methodology Files to Use with SENTRAN7

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Now that we have loaded *DEFAULT.MTH*, its contents are stored in the appropriate parameters in the Edit Module. The following steps will save the values of the parameters in the Edit Module, to a file named *FIRST.MTH*.

6) Enter '1' at the Main Menu prompt to again invoke the Load/Save Module.

7) In response to the prompt for "LOAD OR SAVE METHODOLOGY FILE", as shown in Figure 44, type 'save'. SENTRAN7 will prompt you for the name of the methodology file to create.

8) In response to the prompt for a methodology file name, type 'first'. SENTRAN7 will then create a new methodology file named *FIRST.MTH* which is identical to *DEFAULT.MTH*. You may wish to verify this fact.

9) We can reduce the number of steps required to save *FIRST.MTH* by performing Step 6 and typing 'save first' at Step 7.

10) We may reduce the number of steps further by entering 'save first' at the Main Menu prompt. This will accomplish the same task as Steps 6, 7 and 8 in a single step.

Since we have just generated a file named *FIRST.MTH*, the values stored in this methodology file are still set to the parameters in the Edit Module. If you have not performed the above steps, please do so now, since it is important that the screens which SENTRAN7 presents are identical to those in this tutorial. Our next goal is to modify *FIRST.MTH* in order to generate the following test case:

> *Transmittance for horizontal paths with various optical ranges (1 to 10 km) at several altitudes (0 to 20 km) for a selected wavenumber of 1300 cm^{-1} with MODEL=6 and IHAZE=1*

We will accomplish this task by first editing the necessary input cards as described in the following section.

5.3.3 Using the Edit Module

Before we begin, it is important to remind the reader of the basic methods for moving around in the Edit Module of SENTRAN7 and what to do if you make a mistake. If you enter an incorrect value at a line or inadvertently skip past a line, don't panic. You can move up and down within the card image by using the 'up' and 'dn' commands. For example, if you need to move back to a previous parameter on a card, type 'up' and the number of lines to move back, and press RETURN. The cursor will move back to that parameter, provided that line of the input card is editable. Use these commands then to move the cursor back to the line which is in error and type over your mistake. Note that if the last parameter edited

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was two up from the current parameter you must type 'up 2' to move backward. See Section 4.2.4 for greater detail on the Edit Module's capabilities.

Complete the following steps in order to generate the test case described earlier. You will be providing the values for the standard LOWTRAN7 input parameters. If you are unfamiliar with their meaning, please refer to the LOWTRAN7 manual[1].

1) Type either '3' or 'edit' or some substring of edit (such as 'ed') at the Main Menu prompt (see Figure 43) in order to execute the Edit Module of SEN-TRAN7. The screen for editing Card 1 will appear as shown in Figure 46.

2) The cursor will presently be located on the line MODEL. Note that at any time, the user can type 'help' to display a brief description of the current parameter being entered. For example, type 'help' now, as shown in Figure 47.

The program will display information about the MODEL parameter, as shown in Figure 48.

3) Once you have returned from the help utility, the cursor is returned to the line containing the MODEL parameter. In this tutorial, we would like to use the U.S. Standard Atmosphere model, so type '6' and press RETURN. After this value is entered, the line will reformat itself to reflect the change in the value of the MODEL parameter, while the cursor will move to the next line.

4) We have completed our job of editing Card 1, so type 'pd' (for "page down"). Note that the program asks us if the current card is acceptable. Take this opportunity to check that your Card 1 screen looks like Figure 49.

5) If the card is correct, accept the default (yes) by pressing the RETURN key. Otherwise enter 'n' meaning, "No, the card is not acceptable, I would like to fix it". When you enter 'n', the program returns to the first parameter on the card. Go back to Step 3 of this tutorial and make the appropriate modifications to the card at this point.

6) Completion of Card 1 and acceptance of its contents will move us to the Card 2 screen, as shown in Figure 50.

7) IHAZE will be the active line. We will use the Rural Extinction model, so enter '1'.

8) We will not need any further changes in Card 2, so type 'pd' to move to the next card image. Once we have accepted the contents of Card 2, the Card 3 screen will appear, as shown in Figure 51.

9) H1 will be the first line in Card 3. We would like to perturb this variable to represent calculations performed at altitudes ranging from 0 to 20 km in steps of 2. To do this, type '0 to 20 step 2'.

10) Note that the program will automatically skip the next two parameters (H2 and

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Figure 46. Display of the Screen Used to Edit Card 1

Figure 47. Example of the Procedure to Implement the On-Line Help Utility Within the Edit Module

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SENTRAN HELP UTILITY

'MODEL'   CARD 1

SELECTS ONE OF THE SIX GEOGRAPHICAL-SEASONAL MODEL ATMOSPHERES OR
SPECIFIES THAT USER-DEFINED METEOROLOGICAL DATA ARE TO BE USED:

    = 0   METEOROLOGICAL DATA (HORIZONTAL PATH ONLY)
      1   TROPICAL ATMOSPHERE
      2   MIDLATITUDE SUMMER
      3   MIDLATITUDE WINTER
      4   SUBARCTIC SUMMER
      5   SUBARCTIC WINTER
      6   1976 U.S. STANDARD ATMOSPHERE
      7   NEW MODEL ATMOSPHERE (OR RADIOSONDE DATA)

                        HIT <RETURN> TO CONTINUE

Figure 48. Example of the On-Line Help Information in the Edit Module

SENTRAN7 EDITING UTILITY
EDITING CARD 1

FOLLOWING PARAMS. USE A PERTURBATION LIST (* IMPLIES PERTURBATION RESTRICTIONS)

MODEL *   6
ITYPE *   1
IEMSCT*   0
IMULT *   0
M1 ...   0
M2 ...   0
M3 ...   0
M4 ...   0
M5 ...   0
M6 ...   0
MDEF..   0
IM ...*   0
NOPRT *   0

FOLLOWING PARAMS. USE A PERTURBATION VALUE
TBOUND   0.000
SALB   0.000
ALL PARAMETERS FOR CARD 1 O.K. (Y/N) [Y]

Figure 49. Example of the Screen for Card 1 After All Parameters Have Been
Entered

```
                         SENTRAN7 EDITING UTILITY

                            EDITING CARD 2

FOLLOWING PARAMS. USE A PERTURBATION LIST (* IMPLIES PERTURBATION RESTRICTIONS)

IHAZE * []   0
ISEASN       0
IVULCN       0
ICSTL        0
ICLD   *     0
IVSA   *     0

FOLLOWING PARAMS. USE A PERTURBATION VALUE

VIS ...      0.000
WSS ...      0.000
WHH ...      0.000
RAINRT       0.000
GNDALT       0.000
```

Figure 50. Example of the Screen Used to Edit Card 2

```
                         SENTRAN7 EDITING UTILITY

                            EDITING CARD 3

FOLLOWING PARAMS. USE A PERTURBATION VALUE

H1 ...  []   0.000
H2 ...       0.000
ANGLE        0.000
RANGE        1.000
BETA         0.000
RO ...       0.000

FOLLOWING PARAM. USES A PERTURBATION LIST (* IMPLIES PERTURBATION RESTRICTIONS)

LEN  *    0
```

Figure 51. Example of the Screen Used to Edit Card 3

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ANGLE), since we are computing a horizontal path.

11) RANGE will now be the active variable. Since we would like RANGE to assume all values from 1 to 10 km inclusive, type '**1 to 10**' (we will use the default step size of 1).

12) Our work on Card 3 is complete and we can proceed to Card 4 by typing '**pd**'. Compare your Card 3 image with Figure 52 before proceeding.

13) Once Card 3 has been accepted, Card 4 will appear as shown in Figure 53. Our calculation is concerned only with a single frequency (1300 cm^{-1}). Therefore, we can limit our spectral interval and realize a substantial savings in execution time. V1 will be the current variable, so type '**1300**'. SENTRAN7 will reformat the line and present V1 in terms of cm^{-1} and microns.

14) For V2, enter '**1305**'. Note that even though we are only concerned with the single frequency, 1300 cm^{-1}, LOWTRAN7 cannot calculate spectral intervals with a span of 0, therefore we must enter a V2 of 1305 cm^{-1}.

15) For DV, type '**5**'.

16) Your card should look like the one shown in Figure 54. If it does, accept its contents by hitting RETURN and accepting the default '**y**'. If it does not, take the time now to fix it by entering '**n**' and repeating Steps 13 through 15.

17) SENTRAN7 will now ask if you would like to compile the current input cards, as shown in Figure 55. We want to compile the cards, therefore we should press RETURN, accepting the default (yes). Answering '**y**' to this prompt has the same effect as choosing the Compile Module from the Main Menu.

18) The program will now prompt you for the name of the input file (*.*INP*) to create, as shown in Figure 56. In response to the prompt for an input file name and compile options, type '**test /m/e**', meaning "compile a LOW-TRAN7/MODTRAN input file named *TEST.INP* in MESH form with ERROR logging and automatically generate a *.MTH* file named *TEST.MTH*". Recall that the MESH (/m) option generates all possible combinations of all perturbed input parameters and the ERROR (/e) option causes a list of active absorbers and their spectral range of activity to be written to a file called *SEN.ERR*, along with any compile time errors.

19) SENTRAN7 then displays a screen similar to the one shown in Figure 57, while it compiles the input cards. The active molecular absorbers in the selected spectral range will be displayed. If the list of absorbers fills more than one screen, the message displayed at the bottom of Figure 57 will be shown.

20) Press RETURN to exit the screen and complete the compile option. At this point, we are back at the Main Menu. We will now want to run the appropriate transmission model.

SENTRAN7 EDITING UTILITY

EDITING CARD 3

FOLLOWING PARAMS. USE A PERTURBATION VALUE

```
H1 ...        0.000    TO 20 STEP 2
H2 ...        0.000
ANGLE         0.000
RANGE         1.000    TO 10
BETA          0.000
RO ...        0.000
```

FOLLOWING PARAM. USES A PERTURBATION LIST (* IMPLIES PERTURBATION RESTRICTIONS)

```
LEN    *     0
```

ALL PARAMETERS FOR CARD 3 O.K. (Y/N) [Y]

Figure 52. Example of the Screen for Card 3 After All Parameters Have Been Entered

SENTRAN7 EDITING UTILITY

EDITING CARD 4

THE FOLLOWING PARAMS. CANNOT BE PERTURBED

```
V1 .... []        0.000
V2 ....           20.000
DV ....           5.000
IFWHM             1          (REQUIRED FOR MODTRAN ONLY)
```

Figure 53. Example of the Screen Used to Edit Card 4

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```
SENTRAN7    SUN4/Unix Version                          SPARTA  Inc
                        SENTRAN7 EDITING UTILITY

                           EDITING CARD 4

THE FOLLOWING PARAMS. CANNOT BE PERTURBED

V1 ....      1299.999    CM-1      7.692 MICRONS
V2 ....      1304.999    CM-1      7.662 MICRONS
DV ....         5.000
IFWHM           1        (REQUIRED FOR MODTRAN ONLY)

ALL PARAMETERS FOR CARD 4 O.K. (Y/N) [Y]
```

Figure 54. Example of the Screen for Card 4 After All Parameters Have Been Edited. Note that SENTRAN7's output format routine causes the spectral frequencies to be rounded off incorrectly. The internal representation of the numbers is still correct

```
SENTRAN7    SUN4/Unix Version                          SPARTA  Inc
                        SENTRAN7 EDITING UTILITY

                           EDITING CARD 4

THE FOLLOWING PARAMS. CANNOT BE PERTURBED

V1 ....      1299.999    CM-1      7.692 MICRONS
V2 ....      1304.999    CM-1      7.662 MICRONS
DV ....         5.000
IFWHM           1        (REQUIRED FOR MODTRAN ONLY)

ALL PARAMETERS FOR CARD 4 O.K. (Y/N) [Y]

COMPILE INPUT DECK? [Y]
```

Figure 55. Example of the Prompt to Compile the Current LOWTRAN7/MODTRAN Problem After Editing All Cards

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Figure 56. Example of the Prompt Given to Enter the Name of Input File and the Compiler Options

DEVELOPING INPUT DECK
BASED ON LAST EDITING SESSION

COMPILING TEST.INP AS MESH ERRLOG

LIST OF ACTIVE MOLECULAR ABSORBERS (V1= 1300.0 V2= 1305.0)

H2O ACTIVE REGIONS: 1300.0 TO 1305.0 CM-1

CO2 ACTIVE REGIONS: 1300.0 TO 1305.0 CM-1

N2O ACTIVE REGIONS: 1300.0 TO 1305.0 CM-1

CH4 ACTIVE REGIONS: 1300.0 TO 1305.0 CM-1

SO2 ACTIVE REGIONS: 1300.0 TO 1305.0 CM-1

NH3 ACTIVE REGIONS: 1300.0 TO 1305.0 CM-1
     ...MORE... HIT <RETURN> TO CONTINUE

Figure 57. Example of the On-Line Feedback Provided While SENTRAN7 Compiles the User Specified Input Cards

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5.3.4 Using the Run Module

SENTRAN7 offers the capability of running LOWTRAN7 or MODTRAN from within the menu interface. (Note that it is the user's responsibility to make sure the desired model is present, although SENTRAN7 will notify the user if it cannot find the desired code.) Follow the next steps in order to run the calculations.

1) The user first selects which code to execute, either LOWTRAN7, MODTRAN or MODTRAN run as LOWTRAN7 by entering '5' at the Main Menu. The submenu for choosing which code to run will appear as shown in Figure 58. For this case we will run LOWTRAN7, so we will enter '1'. (NOTE: If you only have the code for MODTRAN, then choose option 3 to run MODTRAN as LOWTRAN7).

2) We are now back at the Main Menu. Notice that option 6 to run the code will reflect which option was chosen in the previous submenu (either LOWTRAN7, MODTRAN, or MODTRAN AS LOWTRAN7).

3) We now wish to run LOWTRAN7, therefore we enter '6' or 'run' at the Main Menu prompt.

4) The program will now prompt you for the name of the input file to use for this run, as shown in Figure 59, with the default being the last input file that was compiled (the file created in Section 5.3.3). We will accept the default file (*TEST.INP*) by pressing RETURN.

5) We now wait for the program execution to complete, at which time we will see the screen shown in Figure 60. The time required to complete a run will depend on many factors, such as the speed of the host computer and the type of calculation.

Figure 58. Example of the Screen Displaying the Program Execution Options

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```
 SENTRAN7       SUNS/Unix Version                           SPARTA    Inc
┌─────────────────────────────────────────────────────────────────────────┐
│            PROGRAM TO BE EXECUTED : LOWTRAN7                              │
│                                                                          │
│        ENTER FILE NAME FOR INPUT DECK [.INP] ? ▯EST.INP                  │
│                                                                          │
│                                                                          │
│                                                                          │
│                                                                          │
└─────────────────────────────────────────────────────────────────────────┘
```

Figure 59. Example of the Prompt Asking the User to Enter the Name of the Input Deck

```
 SENTRAN7       SUNS/Unix Version                           SPARTA    Inc
┌─────────────────────────────────────────────────────────────────────────┐
│                                                                          │
│                                                                          │
│                                                                          │
│                RUNNING LOWTRAN7 FOR TEST.INP                             │
│                                                                          │
│                     ...PLEASE WAIT...                                    │
│                                                                          │
│                                                                          │
│                                                                          │
│                                                                          │
│                                                                          │
│                                                                          │
│                                                                          │
│                                                                          │
│                  EXECUTION COMPLETED                                     │
│                                                                          │
│              PRESS <RETURN> TO CONTINUE▯                                 │
│                                                                          │
└─────────────────────────────────────────────────────────────────────────┘
```

Figure 60. Screen Reporting the Completion of the LOWTRAN7 Calculations

6) The standard LOWTRAN7 *tape7* and *tape8* have now been created as *TAPE7.OUT* and *TAPE8.OUT*, respectively, and contain the output data for the above case. We can now proceed to the Graph and Analyze Module of SENTRAN7.

5.3.5 Using the Graph and Analyze Module For Tutorial #1

Now that we have generated some LOWTRAN7 data, we can proceed to graph and analyze it. Be sure that you have performed the preceding steps of this tutorial and executed LOWTRAN7 so that your results will be consistent with those of this tutorial. Since the G&A Module in SENTRAN7 is fairly versatile, this tutorial is

a cursory overview at best. The best way to master the G&A option is by utilizing the on-line help utility and "playing" with LOWTRAN7/MODTRAN data sets.

We wish to create three plots from the data stored in the *TAPE7.OUT* file from our LOWTRAN7 run (completed in Section 5.3.4 of this tutorial):

Plot #1

> A 3D plot of the total transmittance as a function of the perturbed parameters RANGE and H1 for a wavenumber of 1300 cm^{-1}, plotted at 45° rotation of both axes

Plot #2

> A 3D plot of the derivative of total transmittance with respect to the RANGE (the x axis) as a function of the perturbed parameters RANGE and H1 for a wavenumber of 1300 cm^{-1}, plotted at 45° rotation of both axes

Plot #3

> A 3D plot of the optical depth (total absorbance) as a function of the perturbed parameters RANGE and H1 for a wavenumber of 1300 cm^{-1}, plotted at 45° rotation of both axes

We will begin by creating Plot 1 described above. Follow Steps 1 through 13 to create this plot:

1) Type '7' or **'graph'** or some sub-string of the word **'graph'**, such as **'g'** at the Main Menu prompt. The initial screen displaying the available plots for the input cards defined in the Edit Module will appear, as shown in Figure 61.

2) We would like to plot a transmittance profile (specifically total transmittance), so in response to the prompt for a plot type, enter a '2'. Figure 62 shows the following screen that will appear. This screen prompts the user for the x axis parameter.

3) We would like the x axis to be the perturbed parameter RANGE, so enter a '2' in response to the x axis prompt. The program will now prompt you for the y axis parameter, as shown in Figure 63.

4) We would like the y axis to be perturbed parameter H1, so enter a '2' in response to the y axis prompt. Figure 64 shows the subsequent screen that will appear.

5) Since we have already used two independent axes for our chart, we must select a fixed wavenumber for our data set. In response to the prompt for wavenumber, type '1300'. The G&A option will then prompt you for the units in which frequency dependent data should be expressed (cm^{-1} or microns), as shown in Figure 65.

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SENTRAN7 GRAPHICS & ANALYSIS MODULE

PLOT TYPE: 1) RAW-XYZ   2)   TRANSMITTANCE

PLOT TYPE?   ☐
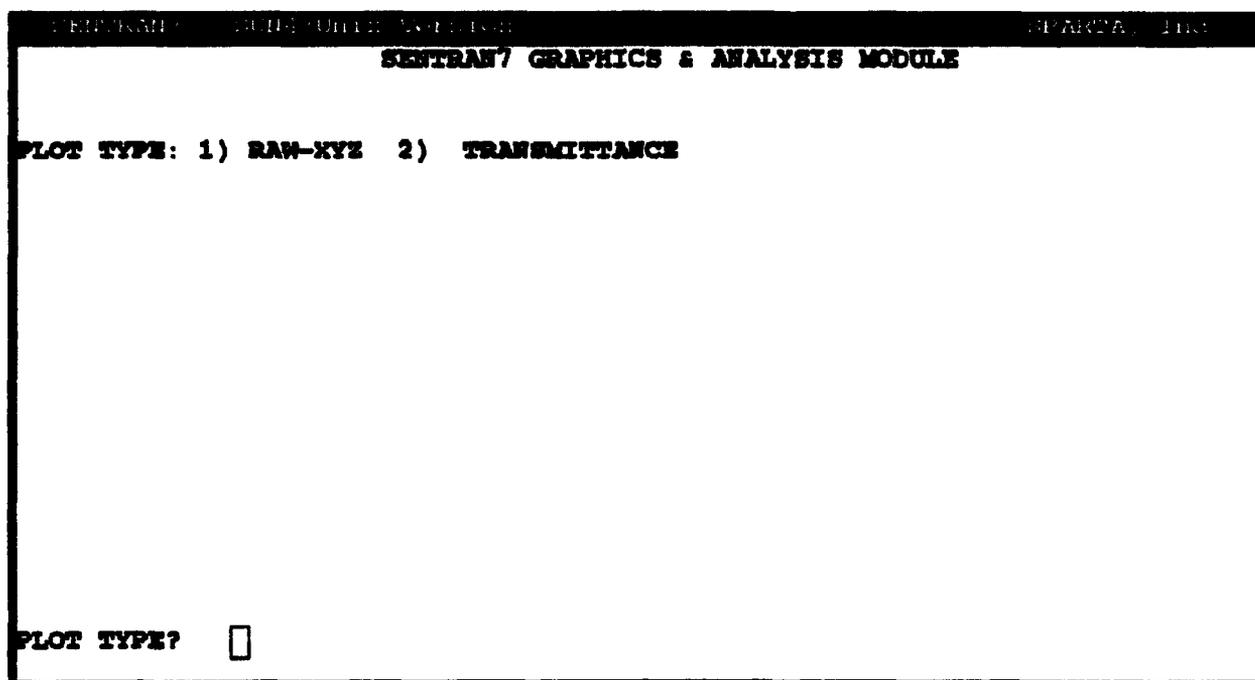
Figure 61. Initial Screen Displayed for the SENTRAN7 Graph and Analyze Option

SENTRAN7 GRAPHICS & ANALYSIS MODULE

PLOT TYPE: TRANSMITTANCE

X-AXIS   : 1) WAVENUMBER   2) RANGE
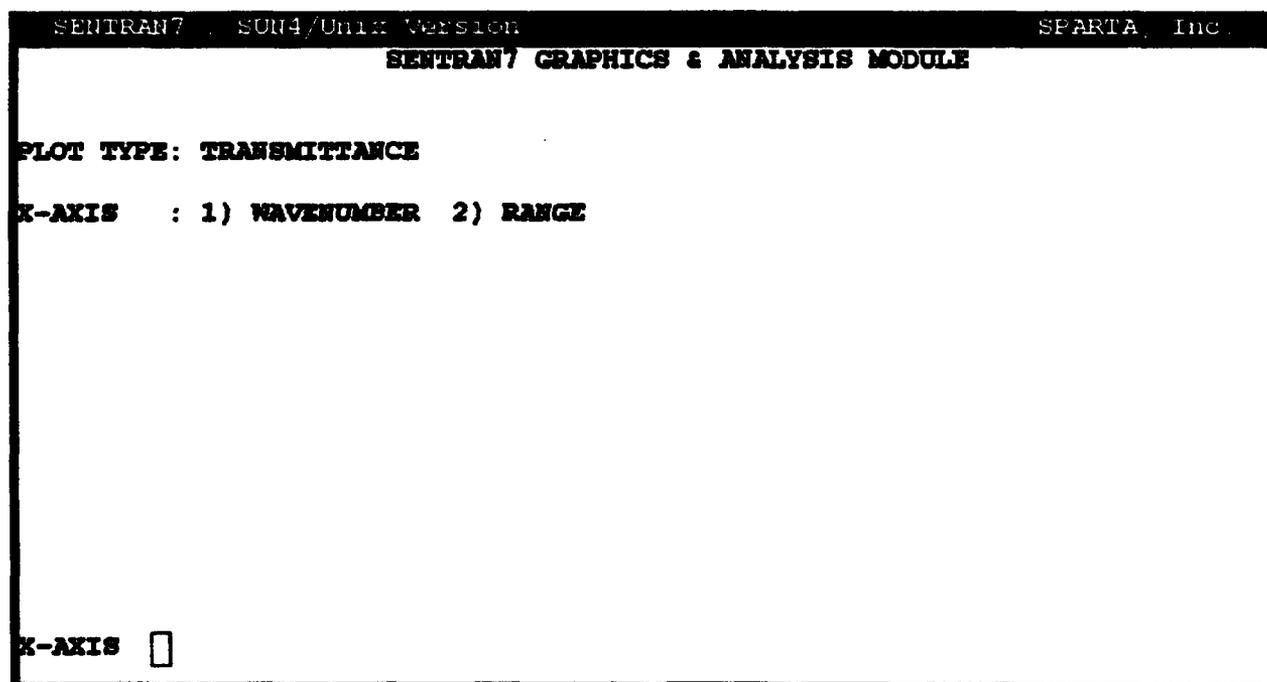
X-AXIS ☐

Figure 62. Screen Prompt Displayed Showing the Choices for the X Axis Parameter

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SENTRAN7 GRAPHICS & ANALYSIS MODULE

PLOT TYPE: TRANSMITTANCE

X-AXIS   : RANGE

Y-AXIS   : 1) WAVENUMBER 2) H1
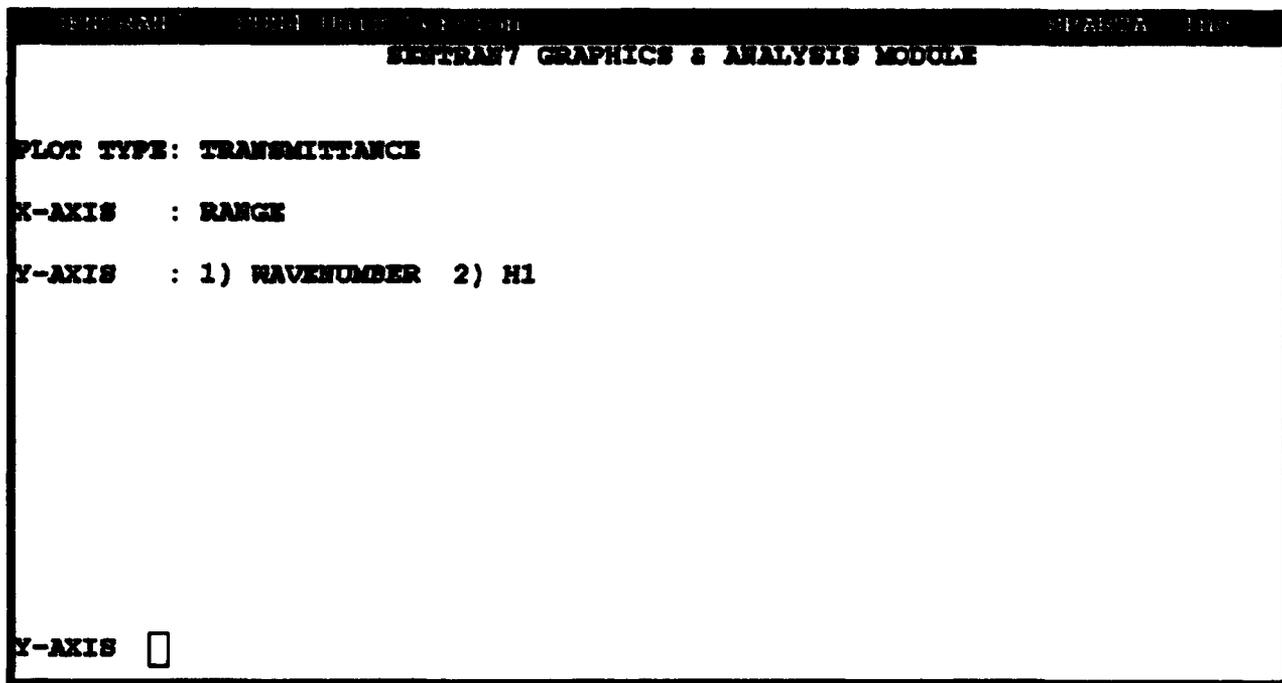
Y-AXIS ☐

Figure 63. Screen Prompt Displayed Showing the Choices for the *Y* Axis Parameter

SENTRAN7   SUN4/Unix Version   SPARTA   Inc

SENTRAN7 GRAPHICS & ANALYSIS MODULE

PLOT TYPE: TRANSMITTANCE

X-AXIS   : RANGE

Y-AXIS   : H1

WAVENUM. : 1300 TO 1305
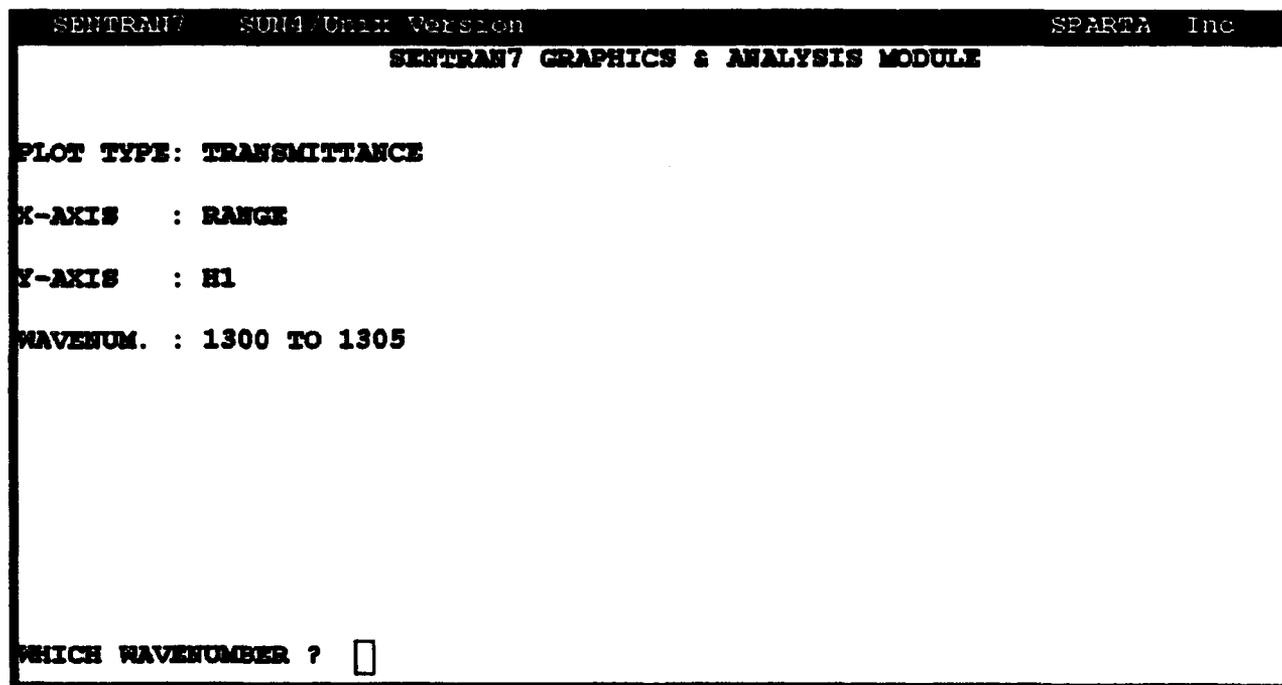
WHICH WAVENUMBER ? ☐

Figure 64. Screen Prompt Requesting the User to Input Wavenumber Range

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```
 MENTRAN7      CODE LIST  VERSION                          INSERTA  1.00
                 MENTRAN7 GRAPHICS & ANALYSIS MODULE

PLOT TYPE: TRANSMITTANCE

X-AXIS    : RANGE

Y-AXIS    : H1

WAVENUM.  : 1300

UNITS OF  :  1) CM-1   2) MICRONS




UNITS ?    []
```
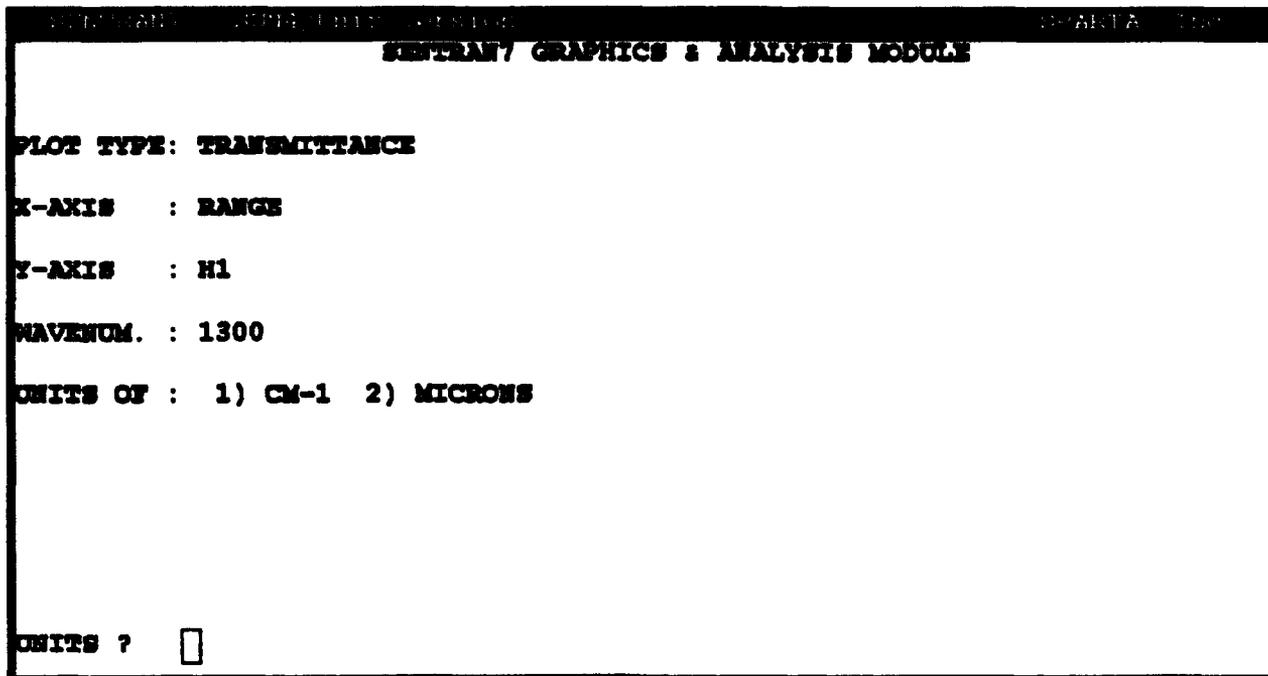
Figure 65. Screen Prompt Requesting the User to Input the Units to Use in Plotting

6) Select '1', for cm^{-1}.

7) You will now be presented with a number of items which may be plotted on the z axis, as shown in Figure 66. The actual choices presented will vary according to the type of calculation which you are performing (based on IEMSCT's value). Recall that we want to plot total transmittance as a function of RANGE and H1, so select item '1' to plot TOTAL TRANSMITTANCE.

8) The final step in the data selection process involves choosing the file from which to read the LOWTRAN7 output data, as shown in Figure 67. In almost all cases the user just needs to accept the default file, either *TAPE7.OUT* or *TAPE8.OUT*. In this case we will accept the default *TAPE7.OUT* by pressing RETURN. You have completed the data selection portion of the G&A option, and the program will now enter the G&A command mode.

9) At the command line, you can obtain a list of available G&A commands by typing 'help'. Figure 68 shows the help screen that will appear.

10) To obtain specific information on any of the G&A commands, you type 'help' and the command you wish information on. For example, type 'help plot' as shown in Figure 69.

The program will display the available help for the PLOT command, as shown in Figure 70.

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SENTRAN7 GRAPHICS & ANALYSIS MODULE

PLOT TYPE: TRANSMITTANCE

X-AXIS   : RANGE

Y-AXIS   : H1

WAVENUM. : 1300

UNITS OF : CM-1

Z-AXIS   :   1) TOTAL   2) H2O   3) UNIF   4) O3   5) TRACE
             6) N2 CONT 7) H2O CONT   8) MOL SCAT   9) AER HYD 10) HNO3
            11) AER ABS 12) LOG TOTAL 13) CO2   14) CO   15) CH4
            16) N2O   17) O2   18) NH3   19) NO   20) NO2
            21) SO2

WHICH TRANSMITTANCE ? □

Figure 66. Screen Prompt Requesting the User to Select the Z Axis Parameter

SENTRAN7 GRAPHICS & ANALYSIS MODULE

PLOT TYPE: TRANSMITTANCE   FILE NAME : TAPE7.OUT

X-AXIS   : RANGE

Y-AXIS   : H1

WAVENUM. : 1300

UNITS OF : CM-1

Z-AXIS   : TOTAL TRANSMITTANCE

Figure 67. Screen Prompt to Enter the Name of the Data File To Be Used by the G&A Module

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```
 SENTRAN   SUN4/Unix Version                       SPARTA, Inc
                     SENTRAN HELP UTILITY

Help is available on the following commands :
              A2T       DXDY      MINIMUM   TITLE

              COSMETIC  DYDX      NEW       T2A

              DX        EXIT      NOSORT    WRITE

              DY        LOG       PLOT      XLABEL

              DDX       MAXIMUM   REFRESH   YLABEL

              DDY       MEAN      SWAP      ZLABEL

  Enter HELP [command you want help on] at the COMMAND prompt

  EXAMPLE:   HELP T2A


                 HIT <RETURN> TO CONTINUE□
```

Figure 68. Screen Displaying the "Help" Options for Graph and Analyze Commands

```
 SENTRAN7   SUN4/Unix Version                      SPARTA, Inc.
                 SENTRAN7 GRAPHICS & ANALYSIS MODULE


PLOT TYPE: TRANSMITTANCE              FILE NAME : TAPE7.OUT

X-AXIS   : WAVENUMBER

Y-AXIS   : RANGE



UNITS OF : CM-1

Z-AXIS   : TOTAL TRANSMITTANCE




COMMAND ? help plot□
```

Figure 69. Screen Showing a Request for "Help" About the PLOT Command

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The PLOT command initiates the plotting sequence. PLOT requires
at least one argument. The argument will generally be a .TEK
output file. However, the name VT240 is a reserved argument
which will send graphical output to the terminal. An output
file name and the VT240 argument can both be provided, causing
output to be directed to the screen and the .TEK file simultaneously.

EXAMPLE :

PLOT TEST VT240

Will form a graphics file TEST.TEK and display the plot on the user's
terminal. After the PLOT command is entered, the user is prompted for
rotation angles. PLOT then proceeds and returns to COMMAND input when
finished.

HIT <RETURN> TO CONTINUE

Figure 70. Screen Showing the "Help" Information Displayed About the PLOT Command

11) If you have a VT240 type terminal, try plotting the data by entering 'plot VT240'. If you do not have a VT240 compatible terminal, plot the graph to a file first by typing 'plot test', this will create the Tektronix file *TEST.TEK*. In either case, the cursor will move to a new field and request rotation angles, as shown in Figure 71. Enter '45,45' meaning "first rotate the data counterclockwise about the z axis and then rotate the data counterclockwise around the original x axis (*i.e.*, tilt out of screen)". Your plot should look like Figure 72.

12) If you were able to plot the graph to the screen using the VT240 command, press the RETURN key when you are done looking at the plot. If you plotted the graph to a file (*TEST.TEK*), you know the plot has been completed when the comment ".TEK FILE : TEST.TEK" appears on the left of the screen and you return to the G&A command line, as shown in Figure 73.

We have now completed our first plot (Plot #1 described above). We will now graph Plot #2, a 3D plot of the derivative of total transmittance with respect to the RANGE (the x axis) versus the perturbed parameters RANGE and H1 for a wavenumber of 1300 cm^{-1}, plotted at 45° rotation of both axes. Step 13 accomplishes this task:

13) Differentiate with respect to the x axis by entering 'dx' at the command line. Note that the program modifies the z axis label to reflect this manipulation.

```
 SENTRAN7    FORTH Unit Version                          SPARTA, Inc
                    SENTRAN7 GRAPHICS & ANALYSIS MODULE


PLOT TYPE: TRANSMITTANCE              FILE NAME : TAPE7.OUT

X-AXIS   : RANGE

Y-AXIS   : H1                         ROTATION  :  45, 45▯

WAVENUM. : 1300

UNITS OF : CM-1

Z-AXIS   : TOTAL TRANSMITTANCE




COMMAND ? plot test
```

Figure 71. Prompt Requesting the User to Enter the Rotation Angles for the Desired Plot


```
X : RANGE                   1.0000E+00 TO  1.0000E+01 (TICK=   1.0)
Y : H1                      0.0000E+00 TO  2.0000E+01 (TICK=   2.0)
Z : TOTAL TRANSMITTANCE     0.1700E-02 TO  0.9836E+00 (TICK=0.0981)
```

Figure 72. Example of Plot #1, A 3D Plot of Total Transmittance as a Function of H1 and RANGE for a 45° Rotation of Both Axes

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SCITRAN/ GRAPHICS & ANALYSIS MODULE

```
PLOT TYPE: TRANSMITTANCE              FILE NAME : TAPE7.OUT

X-AXIS   : RANGE                      .TEK FILE : TEST.TEK

Y-AXIS   : H1                         ROTATION  : 45.00   45.00

WAVENUM. : 1300

UNITS OF : CM-1

Z-AXIS   : TOTAL TRANSMITTANCE




COMMAND ? []
```

Figure 73. Screen Displayed When the Requested Graph Has Been Plotted to a File

Let's plot the data set by typing '**plot VT240**' (or '**plot testdx**' if plotting to a file). Press the RETURN key to accept the default rotation arguments, which should be '**45,45**'. The resultant plot should look like Figure 74.

We will now graph Plot #3, a 3D plot of the optical depth (total absorbance) versus the perturbed parameters RANGE and H1 for a wavenumber of 1300 cm^{-1}, plotted at 45° rotation of both axes. Follow Steps 14 and 15 to create this plot:

14) Recall that we use the T2A command to transform the z axis transmittance data to optical depth. Since our z axis is currently the derivative of transmittance, we first need to refresh the data so that we have total transmittance on the z axis again. This can be done by first typing '**new**' at the command line prompt. The initial G&A screen will appear. Re-answer all of the data input options (*i.e.*, repeat Steps 2 through 8 of the G&A Module for Tutorial #1) so that you have the pertubed parameters RANGE and H1 for the x and y axes, respectively, and TOTAL TRANSMITTANCE on the z axis.

15) Type '**t2a**' to convert the z axis transmittance values to optical depth values. Type '**plot VT240**' and then '**45,45**' to see the results shown in Figure 75.

Again, try seeing which commands are available by typing '**help**'. Experiment

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with the data set by trying as many of these commands as you can, using the on-line help whenever you have difficulties.

X :	RANGE	1.0000E+00 TO 1.0000E+01 (TICK= 1.0)
Y :	H1	0.0000E+00 TO 2.0000E+01 (TICK= 2.0)
Z :	DX TOTAL TRANSMITTANCE	-0.1826E+00 TO -0.9761E-03 (TICK=0.0181)
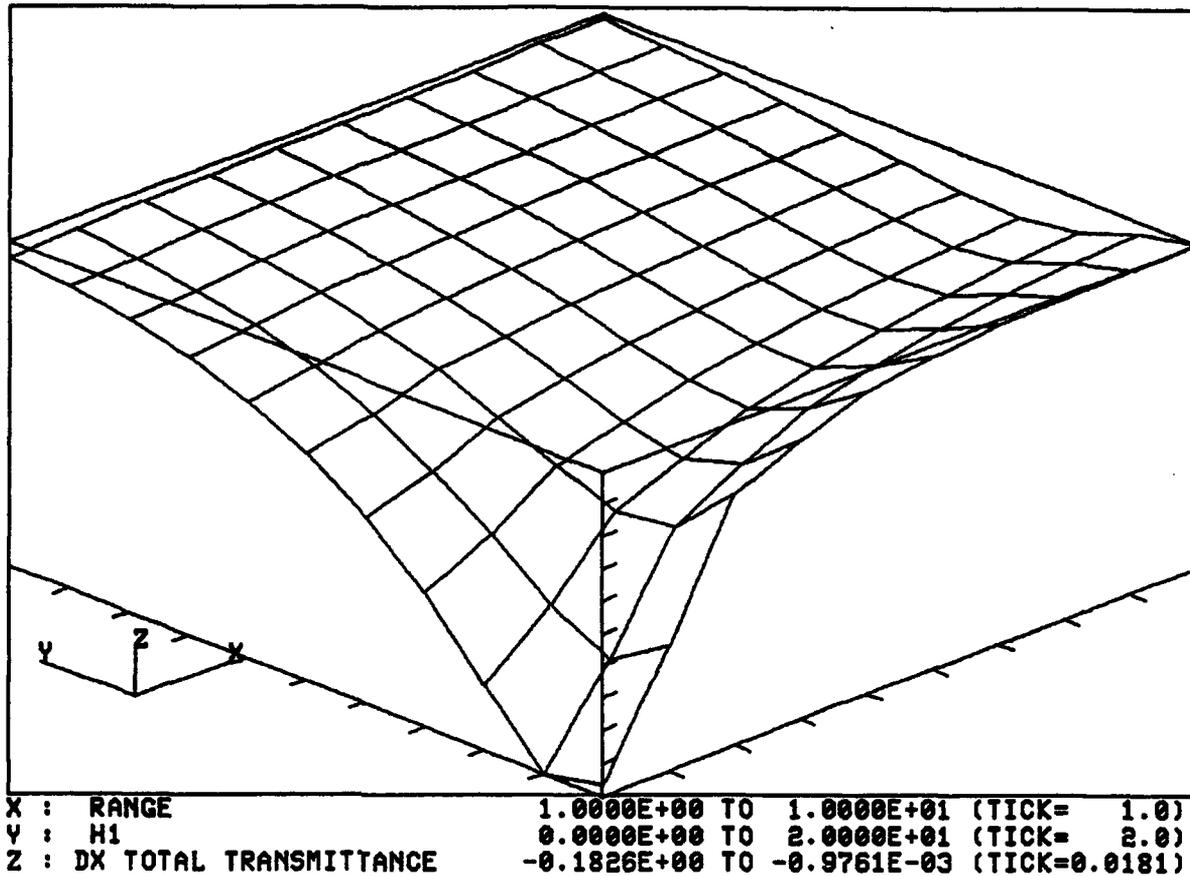
Figure 74. Example of Plot #2, A 3D Plot of Derivative of Total Transmittance With Respect to RANGE as a Function of RANGE and H1 for a 45° Rotation of Both Axes

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X : RANGE	1.0000E+00 TO	1.0000E+01	(TICK= 1.0)
Y : H1	0.0000E+00 TO	2.0000E+01	(TICK= 2.0)
Z : TOTAL ABSORBANCE	0.1653E-01 TO	6.3771E+00	(TICK=0.6360)
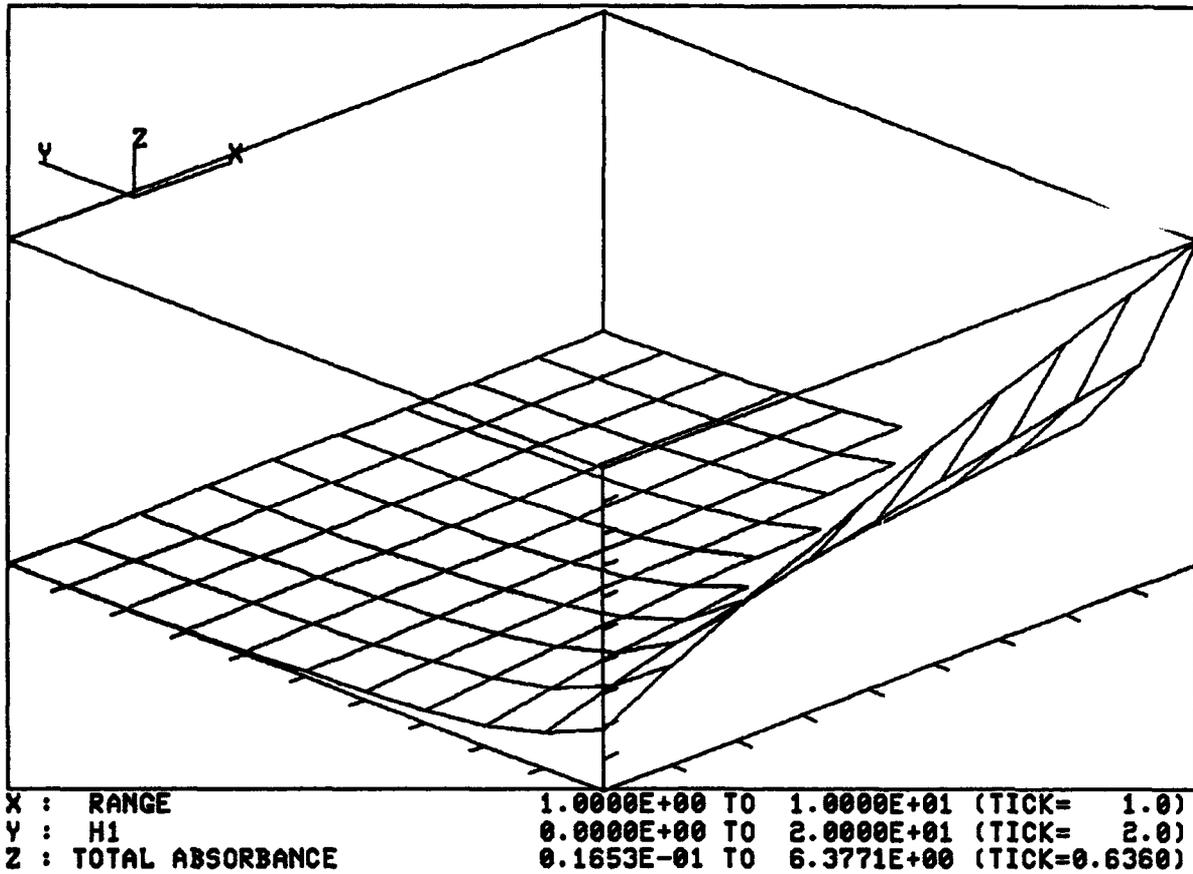
Figure 75. Example of Plot #3, A 3D Plot of Optical Depth as a Function of RANGE and H1 for a 45° Rotation of Both Axes

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5.4 SENTRAN7 Tutorial #2

The following tutorial is not as in depth as the first tutorial given. A step-by-step discussion will not be given as with the first tutorial. Instead, the input parameters for this tutorial are specified for you to enter in through SENTRAN7's Edit Module. Examples of the G&A features and some of the possible plots are shown.

5.4.1 Using the Edit Module

We will begin by editing the input cards to generate the following test case:

Thermal Radiance with single scattering for models 6 (U.S. Standard), 3 (Midlatitude Winter) and 1 (Tropical Atmosphere) and a vertical path from 0 to 32 km with IHAZE = 1, over 400 to 2000 cm^{-1} spectral region at 5 cm^{-1} intervals

Figure 76 summarizes the input parameters for this test case. The steps that follow briefly outline the instructions for editing the input cards in SENTRAN7 in order to generate the test case described above.

```
CARD 1                              CARD 2
------                              ------
   MODEL = 6 3 1                       IHAZE = 1
   ITYPE = 2                           ISEASN = 1
   IEMSCT = 1                          IVULCN = 1
   IMULT = 0                           ICSTL = ICLD = IVSA = 0
   M1=M2=M3=M4=M5=M6=MDEF=0            VIS = WSS = WHH = 0.0
   IM = 0                              RAINRT = 0.0
   NOPRT = -1                          GNDALT = 0.0
   TBOUND = SALB = 0.0


CARD 3                              CARD 4
------                              ------
   H1 = 0.0                            V1 = 400.0
   H2 = 32.0                           V2 = 2000.0
   ANGLE = 0.0                         DV = 5.0
   RANGE = 0.0                         IFWHM = 1
   BETA = RO = 0.0
   LEN = 0
```

Figure 76. Summary of Input Parameters for Tutorial #2

1) Type either '3' or 'edit' at the Main Menu in order to enter the Edit Module of SENTRAN7. The screen for editing Card 1 will appear.

2) For the MODEL parameter we wish to use three different models, U.S. Standard, Midlatitude Winter and Tropical Atmosphere, so enter '6 3 1' on the first line of Card 1.

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3) ITYPE will now be the active line. Enter '2' to indicate a vertical path between two altitudes.

4) For IEMSCT, enter '1' to execute the program in radiance mode.

5) Set IMULT equal to '0' for single scattering.

6) Hit RETURN until you reach the line containing the NOPRT parameter. Enter '-1' so that data will be written to *TAPE8.OUT* as well as *TAPE7.OUT*. *TAPE8.OUT* will contain data for the differential transmittance (DTAU) and the Black Body Function.

7) We are now done editing Card 1. Enter '**pd**' to advance to Card 2. Verify that the parameters on Card 1 match those summarized in Figure 76 for Card 1. If they do, accept Card 1 by hitting RETURN. If they do not, enter 'n' and repeat Steps 2 through 7 of this tutorial.

8) We will now be editing Card 2. IHAZE will be the active line in Card 2. We will use the Rural Extinction aerosol model, so enter '1' for IHAZE.

9) ISEASN will be the active line; enter '1' for a Spring - Summer aerosol profile season.

10) Enter '1' for IVULCN to select a background stratospheric profile and extinction.

11) The rest of the parameters on Card 2 should be set to '0'. If they are, enter '**pd**' to advance to Card 3. If they are not, continue editing Card 2 and set these variables to '0'. Again check the contents of your Card 2 with the summary of input parameters in Figure 76 for Card 2. If they are correct, accept the contents of Card 2 by hitting RETURN. If they do not, enter 'n' and repeat Steps 8 through 11.

12) We will now be editing Card 3, with H1 being the active line. We wish to use a vertical path from 0 to 32 km, so enter '0' for H1.

13) Then enter '32' for H2.

14) The rest of the parameters on Card 3 should be set to '0'. If they are, enter '**pd**' and accept Card 3 after comparing the contents of your card to the summary given in Figure 76 for Card 3.

15) This will advance us to Card 4. We wish to perform calculations over a 400 to 2000 cm^{-1} spectral region at 5 cm^{-1} intervals. So for the initial frequency V1, enter '**400**'. The program will automatically reformat the line and display V1 in cm^{-1} and microns.

16) For the final frequency V2, enter '**2000**'.

17) For the frequency increment DV, enter '**5**'.

18) We are done editing Card 4. Enter '**pd**' and accept the contents of Card 4.

Note that we are not concerned with the value of IFWHM since we will be running LOWTRAN7 and not MODTRAN.

19) Once we have accepted Card 4, SENTRAN7 will prompt you if you want to compile the input parameters. Accept the default 'y' by hitting RETURN so that we now enter the Compile Module of SENTRAN7.

5.4.2 Using the Compile and Run Modules

20) The program now prompts you for the name of the input file (*.INP) to create and for the compiler options. Compile the input parameters to produce the file TEST2.INP in NOMESH form without ERROR logging by entering 'test2 /nomesh'.

21) After the program finishes compiling the input file, SENTRAN7 returns to the Main Menu. We can now run LOWTRAN7 for the test case we have just created. Make sure that Option 5 on the Main Menu says RUN LOWTRAN7 (or RUN MODTRAN as LOWTRAN7). If it does not, first choose Option 5 to SELECT LOWTRAN7/MODTRAN and select LOWTRAN7 (or MODTRAN as LOWTRAN7) from the subsequent submenu.

22) We are now ready to execute LOWTRAN7, so enter '6' or 'run' at the Main Menu prompt. Wait for the program to notify you that execution has completed before hitting RETURN and returning to the Main Menu.

We can now proceed to the Graph and Analyze Module of SENTRAN7.

5.4.3 Using the Graph and Analyze Module for Tutorial #2

We wish to create two plots from the data created from Tutorial #2:

Plot #1

A 3D plot of the total transmittance as a function of wavenumber and the perturbed parameter MODEL, plotted at viewing angles of -11.25° and 11.25°

Plot #2

A 3D plot of the differential transmittance (DTAU) as a function of layer and wavenumber for a Midlatitude Winter atmosphere, plotted at viewing angles of -45° and 11.25°

23) Enter the G&A Module by entering '7' or 'graph' at the Main Menu. The initial screen and types of plots available for this case are shown in Figure 77.

24) We first want to create Plot #1. The option to plot total transmittance can be found under the ATM RADIANCE plot type, so enter '2' for this plot type at the command prompt. Let the x axis be the wavenumber in units of cm^{-1}
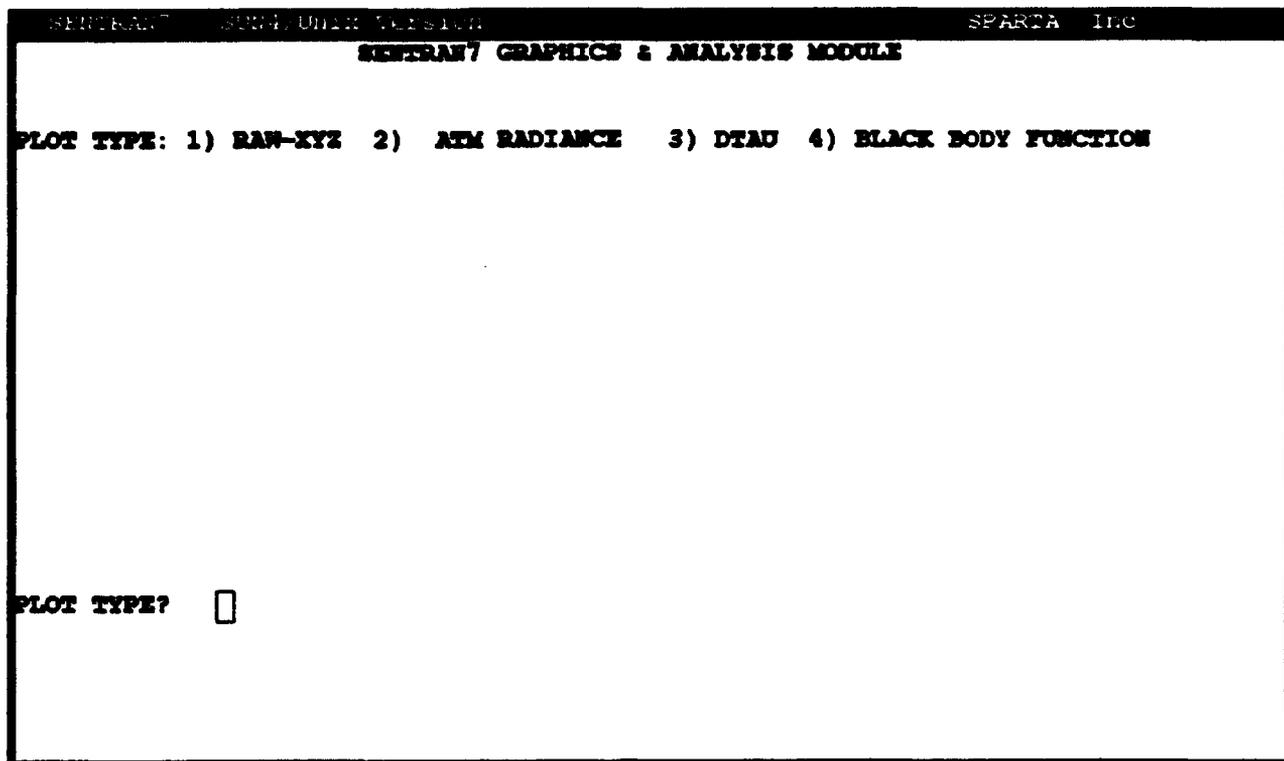
Figure 77. Example of the Initial Screen for the SENTRAN7 Graph and Analyze Features for Tutorial #2

and the y axis be the different model numbers. Then let the z axis be total transmittance. Read in the *TAPE7.OUT* file and plot the data with rotation angles of -11.25° and 11.25°. This plot is shown in Figure 78.

25) We next want to create Plot #2. We first need to refresh the data set by typing 'new' at the G&A command prompt to return to the initial G&A menu. Now choose the plot type to plot DTAU by entering a '3'. Note that the x axis parameter is automatically set to LAYER # and the y axis parameter is set to WAVENUMBER. Choose the cm^{-1} units at the prompt for the units. For the z axis we can choose to plot DTAU or DTAU/LAYER THICKNESS. We want to plot DTAU, so enter '1' at the prompt for the z axis paramter. Read in *TAPE8.OUT* and plot the graph with rotation angles of -45.0° and 11.25°. This plot is shown in Figure 79. Note that the x axis increases into the foreground. Also note that the program can ONLY plot the first group of data in the output file (MODEL = 3), and does not plot the cases for MODEL = 6 or 1. Any time DTAU, the Black Body Function or the Flux plots (IEMSCT = 2) are plotted, only the first perturbation case in the output file is plotted. Which perturbation case is first in the output file depends on if the input file was compiled as NOMESH or MESH. To plot these other cases you must edit the

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input cards so that the desired perturbation to plot is first and then compile the input cards as MESH. For best results when plotting layerwise plots such as this, the user should not use any perturbations but simply edit the input cards for one particular case to plot.


```
X : WAVENUMBER            4.0000E+02 TO  2.0000E+03 (TICK= 150.0)
Y : MODEL                    1   3   6
Z : TOTAL TRANSMITTANCE   0.0000E+00 TO  0.9096E+00 (TICK=0.0909)
```
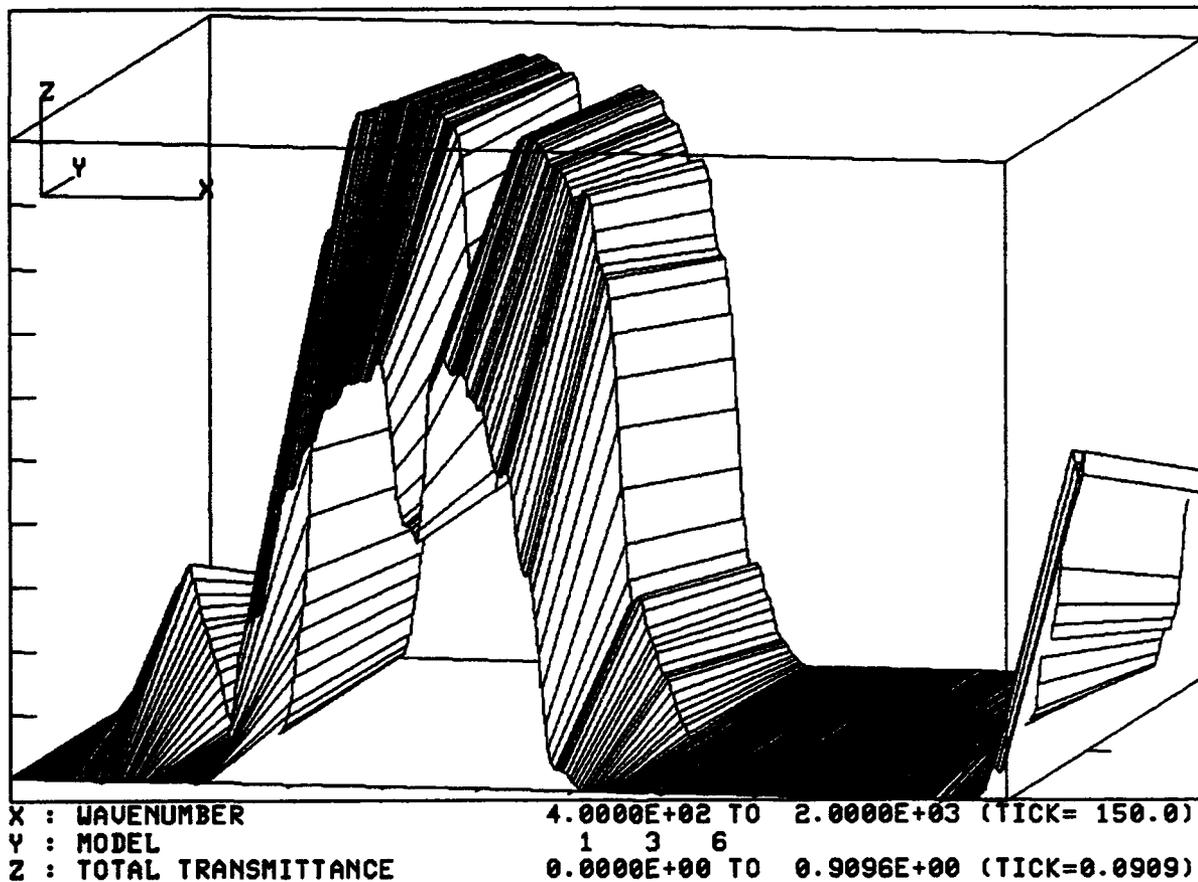
Figure 78. Plot #1, A 3D Plot of Total Transmittance as a Function of Wavenumber and Model Atmosphere Number for Viewing Angles of -11.25° and 11.25°

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```
X : LAYER #           1.0000E+00 TO  2.7000E+01 (TICK=   3.0)
Y : WAVENUMBER        4.0000E+02 TO  2.0000E+03 (TICK= 150.0)
Z : DTAU              0.0000E+00 TO  1.0000E+00 (TICK=0.1000)
```
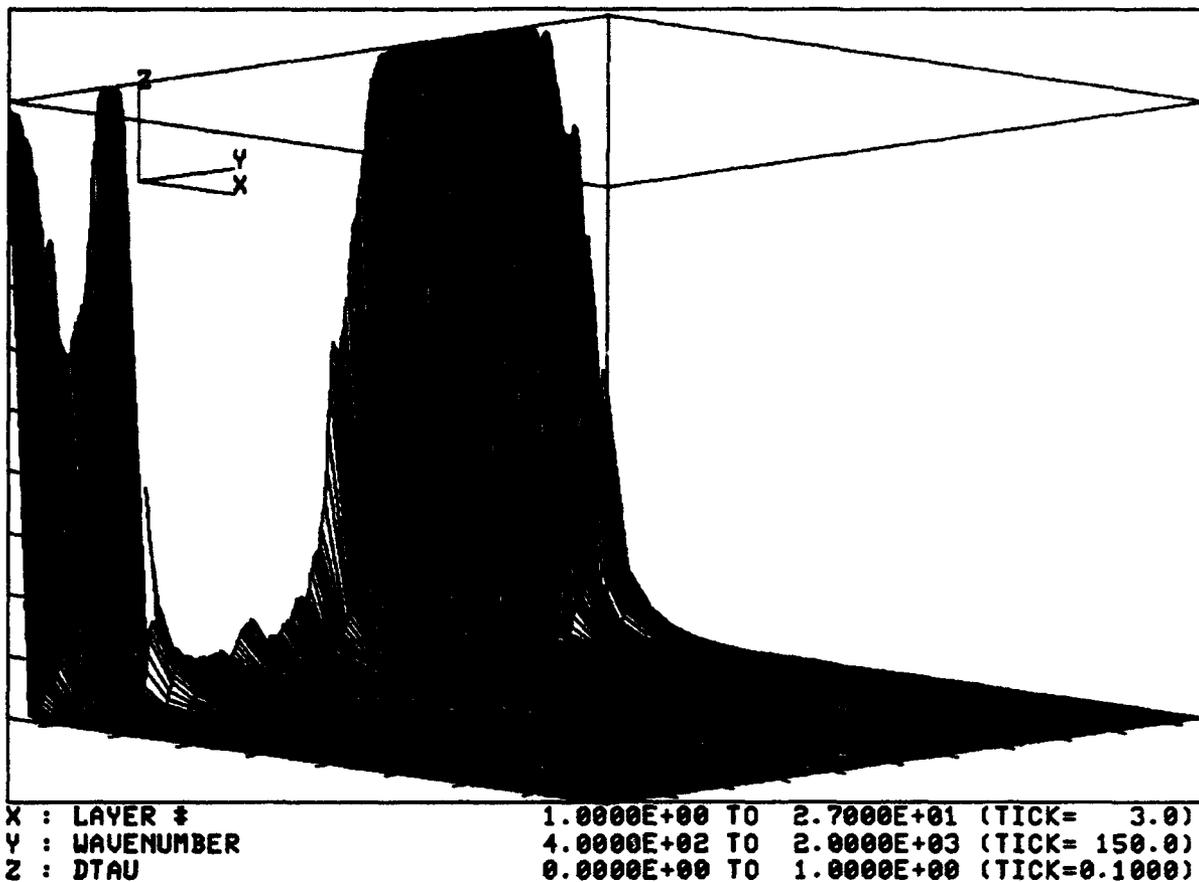
Figure 79. Plot #2, A 3D Plot of Differential Transmittance as a Function of Layer Number and Wavenumber, for a Midlatitude Winter Atmosphere and Viewing Angles of -45° and 11.25°

6 SUMMARY AND RECOMMENDATIONS FOR FUTURE STUDIES

6.1 Summary

SENTRAN7 is a user friendly interface system to LOWTRAN7 and MODTRAN for use in automating the generation of input decks. The code is highly useful in evaluating the impact of atmospheric perturbations on atmospheric transmittance and radiance. To facilitate these sensitivity studies, SENTRAN7 includes the autonomous post processing of LOWTRAN7 and MODTRAN outputs for data extraction and graphical display, as well as extensive data analysis tools.

This report describes a number of new features that have been added to the SENTRAN7 code. The two major enhancements are an error checking package for user-defined atmospheres (*i.e.*, the Card 2C and 2D series) and the capability to impose deterministic and random perturbations on atmospheric variables in the Card 2C series. Other new features include options to view the contents of files and to save LOWTRAN7 and MODTRAN output as customized file names. These new features are based on constructive feedback from prospective users in the scientific community.

6.2 Recommendations for Future Studies

6.2.1 Incorporation of Aerosol and Other Climatologies

Aerosols can have a significant impact on the radiative properties of the atmosphere. These impacts exhibit both spatial and temporal variability, especially in the troposphere. Typically, aerosols in a particular geographic region are some derivative of the underlying surface and/or any other local production mechanisms. Also, airborne aerosols are influenced by large-scale transport mechanisms, such as general circulation patterns and convection processes, and small scale processes including water uptake, chemical reactions and coagulation.

The aerosol inputs within the framework of LOWTRAN7 and MODTRAN require users to have a prior knowledge of the location under consideration, as well as a general understanding of aerosol properties. When performing radiative studies in the arctic region, for example, users need to realize that the wintertime aerosols are strongly influenced by man-made pollutants from northern Europe. In many cases however, users are not familiar with local influences and, consequently, they may be using an incorrect aerosol model in LOWTRAN7 and MODTRAN. Furthermore, novice users may perturb aerosol parameters within SENTRAN7 without knowing if the degree of the perturbation is reasonable.

A future enhancement to SENTRAN7 would permit users to access a set of aerosol climatologies by means of a simple interface system. Specifically, users will specify a series of easily obtainable parameters, such as the time of year

and the site latitude and longitude, and SENTRAN7 will automatically assign an appropriate aerosol to the boundary layer. Such a feature will facilitate those SENTRAN7 sensitivity studies that pertain to climatic modeling issues and remote sensing applications. Additionally, it will make LOWTRAN7 and MODTRAN less hostile toward users whose field of expertise does not include aerosols. At some point, the on-line database could be expanded to include information on clouds, temperature, and humidity.

It is worth mentioning that sets of aerosol climatologies are currently available. d'Almeida and Koepke[10] have critically reviewed the scientific literature and derived a global distribution of aerosol optical properties. This aerosol climatology makes use of ten aerosol components and ten aerosol types. The aerosol types and radiative characteristics are horizontally distributed in a global grid of $5°$ latitude and $5°$ longitude. The temporal variation is considered on a monthly basis.

6.2.2 Windows-Based Menu System

Many prospective users of SENTRAN7 have expressed discontent with its menu system. That is, SENTRAN7 does not recognize standard cursor control keys on the keyboard, such as the arrow keys and the "page up" and "page down" keys. Instead, users are forced to learn a set of primitive and somewhat archaic commands as the method of moving within the Edit module menus and perturbing variables. This often leads to fustration because many users instinctively begin pressing arrow keys as soon as they enter the Edit module.

The "user friendliness" of SENTRAN7 can be improved significantly by converting its menu system to a state-of-the-art windows-based menu system. One possible software candidate would be a Motif-based system under X Windows. Additionally, SENTRAN7 graphics could be replaced with Xlib graphics calls. Although Motif/X Windows operates under a Unix environment, most VAX systems now support this feature.

Note that this effort may prove to be a substantial undertaking. First, the entire SENTRAN7 menu system would have to be converted to C programming language to support Motif. To facilitate the conversion, one could use a Graphical User Interface (GUI) tool kit to design the menu layout. Furthermore, SENTRAN7's menu system, in its present framework, is highly intertwined with the remainder of the code. Thus, it may less cumbersome to convert the rest of the code to C programming language rather than developing an interface to the Motif-based menu system. Commercial packages are available to convert some of the supporting Fortran routines to C programming language.

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[10] d'Almeida, G.A.. and Koepke, P. (1988) "An approach to a global optical aerosol climatology", in *Aerosols and Climate*, P.V. Hobbs and M.P. McCormick (Eds.), A. Deepak Publishing, Hampton, VA..

6.2.3 Sensitivity Studies With a "Build Your Own" Aerosol Layer

In their current framework, LOWTRAN7 and MODTRAN allow users to insert arbitrary aerosol layers by means of parameters in the Card 2C and 2D series. Specifically, users must supply aerosol extinction coefficient at 0.55 μm and scaling factors for the extinction coefficient, absorption coefficient and asymmetry parameter at the wavelengths of interest.

In many cases however, users only have measurements of the size distribution of an aerosol. To conform with the input requirements for LOWTRAN7 and MODTRAN, users must perform a set of (off-line) intermediate calculations to convert these measured size distributions into extinction coefficients, absorption coefficients and so forth. Typically, the aerosol is modeled as a collection of spheres and the radiative properties are then calculated by means of Mie scattering theory.

A useful feature in SENTRAN7 would permit users to "build their own" aerosol layers. Users will specify number densities versus altitude, mode radii, and indices of refraction for the aerosol and SENTRAN7 will automatically set up the appropriate input files for LOWTRAN7 and MODTRAN. Effectively then, the radiative properties of the aerosol will be calculated within SENTRAN7, transparent to users. Such a feature has already been implemented into the lidar simulation code BACKSCAT Version 3.0.[11] BACKSCAT Version 3.0 models the "build-your-own" aerosol layer as a collection of spheres, although the code makes use of approximations because Mie calculations can be time consuming for aerosols that are large compared with the wavelength.

A "build-your-own" aerosol could probably be simulated with parameters in the Card 2C and 2D series. In keeping with the sensitivity aspect of SENTRAN7, users will be permitted to perturb parameters such as the aerosol number density and mode radii. Such a feature will allow users to rapidly answer questions such as, "how sensitive is atmospheric transmission to changes in aerosol mode radii of 20%?" As part of this feature, SENTRAN7 will also contain an internal database of indices of refraction for common substances, such as water and ice, in case users are unsure about values to use for the Mie calculations.

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[11] Hummel, J.R., Longtin, D.R., DePiero, N.L., and Grasso, R.J. (1992) *BACKSCAT Lidar Simulation Version 3.0: Technical Documentation and Users Guide*, Directorate of Geophysics, Phillips Laboratory, PL-TR-92-2328, (ADA267296).

6.2.4 Other PL Codes

The current version of SENTRAN7 can adequately serve as a sensitivity analysis tool for LOWTRAN7 and MODTRAN. However, the Geophysics Directorate is in the process of upgrading and releasing several of its codes. MODTRAN 2[12] will be officially released by the end of 1993. Additionally, GP plans to release three new codes in the near future. The first code is named MOSART[13] which is a combination of MODTRAN and APART.[14] Its main features permit greater flexibility for terrain spectral variation, cloud types, and scintillation. The second code is called SAMM[13] which combines the scattering modules of MODTRAN with the equivalent line width capability of SHARC.[15] SAMM is applicable for altitudes between 0 and 300 km. The third code is called MODTRAN-A which will have a full ultraviolet module called AURIC.[16] MODTRAN-A will also contain additional atmospheric layering with up to 80 available layers.

With the release of these new atmospheric codes, the next logical step is to adapt SENTRAN7 or concepts from SENTRAN7 to work with them. The use of SENTRAN7 with MODTRAN 2 is probably the most straightforward because the input stream is essentially the same as LOWTRAN7 and MODTRAN.[17] The other GP codes would require more effort, although many of the supporting subroutines from SENTRAN7 could be used as is.

Finally, no work was performed on SENCODE, a sensitivity package for FAS-CODE[18] during the current effort. SENCODE, which began as a parallel effort to SENTRAN7, is incomplete and additional work must be performed on it. A goal of future work should be to get SENCODE to the point where it performs like SENTRAN7. Specifically, future work should include the following items:

[12] Anderson, G.P., Chetwynd, J.H., Hoke, M.L., Kneizys, F.X., Abreu, L.W., Robertson, D.C., Berk, A., Acharya, P., Theriault, J.M. (1993) *MODTRAN 2: Suitability for Remote Sensing*, OE/Aerospace Sensing SPIE Proceedings, Orlando, FL, April, 1993.

[13] Anderson, G.P. (1993) *Code Overview*, Presentation to Joint Phillips-Wright Laboratories Atmospheric Propagation Workshop, Dayton, OH, 18 May 1993.

[14] Cornette, W.M. (1990) *Atmospheric Propagation and Radiative Transfer (APART) Computer Code (Version 7.00)*, R-062-90, Photon Research Associates, Inc., San Diego, CA.

[15] Sharma, R.D., Duff, J.W., Bernstein, L.S., Gruninger, J.H., Sundberg, R.L., Robertson, D.C., Healer, R.J. (1991) *SHARC, the Atmospheric Radiation and Transmittance Code for Altitudes from 50 to 300 km*, Presented at the 1991 Meeting of the IRIS Targets, Backgrounds, and Discrimination Meeting, January, 1991.

[16] Hugenin. R., Hickey, R., Minschwaner, K., Anderson, G., Hall, A., and Huffman, R. (1991) *AURIC (Atmospheric Ultraviolet Radiance Integrated Code) An Update*, Presentation to the Annual Review Conference on Atmospheric Models, Hanscom, AFB, MA, 11-12 June 1991.

[17] Anderson, G. (1993) private communication.

[18] Clough, S.A., (1985) *Preliminary User Instructions for FASCOD2*, Letter, AFGL/OPI, Hanscom AFB, MA, October 1985.

1. Make SENCODE compatible with all FASCODE options

2. Add an on-line help option in the Edit Module

3. Provide a Graph and Analyze Module for viewing FASCODE sensitivity analyses.

The last item is a formidable task because it involves reading FASCODE output files. Initially, the Graph and Analyze Module should be able to interpret the laser line option because these results are always written to FASCODE's *TAPE6* file as formatted output. To interpret standard FASCODE output, one possible route is through FASCODE's internal plot option. The input parameter JOUT in the Card 10 Series could be defined so that FASCODE writes plot values to a file as formatted output. In turn, these formatted files could be read by SENCODE using routines like those that read *tape7* and *tape8* in SENTRAN7. Because many types of plots can be generated by FASCODE (*i.e.*, transmittance, radiance), a major part of developing a Graph and Analyze Module will be to:

1. Generate a sequence of prompts that ask users what they want to graph and analyze, based on the problem they specified

2. Get SENCODE to read FASCODE output files and then plot the quantity (*i.e.*, optical depth, transmittance or radiance) requested by the user.

References

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2. Kneizys, F.X., Shettle, E.P., Gallery, W.O., Chetwynd, J.H., Abreu, L.W., Selby, J.E.A., Clough, S.A., and Fenn, R.W. (1983) *Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 6*, Air Force Geophysics Laboratory, Hanscom AFB, MA, AFGL-TR-83-0187, (ADA137796).

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4. Tomiyama, K. and Hogan, M. (1988) *Sensitivity Evaluation Plan for LOW-TRAN*, Department of Electrical Engineering, The Pennsylvania State University.

5. Longtin, D.R., DePiero, N.L., Pagliughi, F.P., and Hummel, J.R. (1991) *SEN-TRAN7: The Sensitivity Analysis Package for LOWTRAN7 and MODTRAN*, Phillips Laboratory, Hanscom AFB, MA, PL-TR-91-2290(II), (ADA251595).

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10. d'Almeida, G.A.. and Koepke, P. (1988) "An approach to a global optical aerosol climatology", in *Aerosols and Climate*, P.V. Hobbs and M.P. Mc-Cormick (Eds.), A. Deepak Publishing, Hampton, VA..

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12. Anderson, G.P., Chetwynd, J.H., Hoke, M.L., Kneizys, F.X., Abreu, L.W., Robertson, D.C., Berk, A., Acharya, P., Theriault, J.M. (1993) *MODTRAN 2: Suitability for Remote Sensing*, OE/Aerospace Sensing SPIE Proceedings, Orlando, FL, April, 1993.

13. Anderson, G.P. (1993) *Code Overview*, Presentation to Joint Phillips-Wright Laboratories Atmospheric Propagation Workshop, Dayton, OH, 18 May 1993.

14. Cornette, W.M. (1990) *Atmospheric Propagation and Radiative Transfer (APART) Computer Code (Version 7.00)*, R-062-90, Photon Research Associates, Inc., San Diego, CA.

15. Sharma, R.D., Duff, J.W., Bernstein, L.S., Gruninger, J.H., Sundberg, R.L., Robertson, D.C., Healer, R.J. (1991) *SHARC, the Atmospheric Radiation and Transmittance Code for Altitudes from 50 to 300 km*, Presented at the 1991 Meeting of the IRIS Targets, Backgrounds, and Discrimination Meeting, January, 1991.

16. Hugenin. R., Hickey, R., Minschwaner, K., Anderson, G., Hall, A., and Huffman, R. (1991) *AURIC (Atmospheric Ultraviolet Radiance Integrated Code) An Update*, Presentation to the Annual Review Conference on Atmospheric Models, Hanscom, AFB, MA, 11-12 June 1991.

17. Anderson, G. (1993) private communication.

18. Clough, S.A., (1985) *Preliminary User Instructions for FASCOD2*, Letter, AFGL/OPI, Hanscom AFB, MA, October 1985.

There are several types of files associated with the SENTRAN7 system. Table A-1 lists the file types, their default extensions, and the origin of the files. The length of a file name is restricted to 20 characters. If the user enters a file name containing more than 20 characters, SENTRAN7 will truncate the file name to the first 20 characters. The structure and use of each type of file is also discussed in this appendix.

Table A-1. Default File Names Associated With SENTRAN7

FILE NAME AND EXTENSION	ORIGIN	CONTENTS
*.MTH	SENTRAN7	Methodology files
*.INP	SENTRAN7	LOWTRAN7/MODTRAN input files
*.PRO	User	Model atmosphere data (i.e., Card 2C series)
*.AER	User	Aerosol extinction coefficients (i.e., Card 2D series)
*.PHS	User	Aerosol phase functions (i.e., Card 3B series)
*.RND	User	Layer standard deviations and correlation lengths for random perturbations
*.OUT	LOWTRAN7/MODTRAN	Output data used for plotting
*.TP6,TP7,TP8	SENTRAN7	Customized output data files from LOWTRAN/MODTRAN
*.3D	User/SENTRAN7	Raw x, y, z data
*.TEK	SENTRAN7	Tektronix graphics files
*.COS	SENTRAN7	Cosmetic data
SEN.ERR	SENTRAN7	Error log and major absorber information
SEN.LOG	SENTRAN7	User input log and error checking output
RANDOM1.DAT	SENTRAN7	Tabulated random perturbation profiles
RANDOM2.DAT	SENTRAN7	Statistical analysis of random perturbation profiles

* is a wildcard indicating arbitrary text

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A.1 Methodology File

Methodology files contain information necessary for setting the parameters in the Edit Module to specific values, including both nominal values and perturbation directives. They provide a convenient means for saving input data for LOWTRAN7 and MODTRAN sensitivity studies for later recall. Methodology files are generally written and read via the Load/Save Module, with the exception of a special file called *LAST.MTH*. The file, *LAST.MTH*, is saved after every completed editing session (*i.e.*, an editing session in which the user does not proceed to the Main Menu via the END command) and every compilation. This file is loaded every time that SENTRAN7 is started. Since SENTRAN7 extracts vital information from this file, the user is cautioned against tampering with it in any way. Methodology files have default extensions of *.MTH*.

A.2 LOWTRAN and MODTRAN Input File

Input files are files containing the LOWTRAN7 and MODTRAN input parameters. Input files are generated by SENTRAN7's Compile Module. They are given the default extension of *.INP*.

A.3 Model Atmosphere Data File

Model atmosphere data files have *.PRO* default extensions and represent the Card 2C series in LOWTRAN7 and MODTRAN. Data in this input stream include layer-by-layer profiles of temperature, water vapor, trace gases and aerosol extinction. Details about variable definitions and record formats can be found in the manual for LOWTRAN7[1] and MODTRAN.[3]

Because the Card 2C series usually involves many input records, the *.PRO* files must be created off-line by the user. However, the SENTRAN7 package does include six *.PRO* files which represent the six model atmospheres in LOWTRAN7 and MODTRAN. Temperature, water vapor and trace gas amounts in these files were taken directly from the LOWTRAN7 and MODTRAN databases. The aerosol extinction profiles represent a 23 km surface visibility in the boundary layer and background values in the free troposphere, stratosphere and upper atmosphere.

The *.PRO* files included with the SENTRAN7 package can be used to do sensitivity studies for the standard model atmospheres. To do this, the user must first set the MODEL parameter on Card 1 equal to 0 or 7. When the Edit Module asks for a filename for the Card 2C series, the user then enters 'model1', 'model2', etc. After a filename is specified, the next screen contains a list of input parameters for Card 2C where users can assign their percent perturbations. Additionally, novice users can use the model *.PRO* files as guides to create and debug their own

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atmosphere profiles. Note that if aerosol extinction profiles are included in a *.PRO* file, they will override the values of other aerosol parameters on Card 2.

A.4 Aerosol Extinction Coefficients Data File

Files with *.AER* extensions represent the Card 2D series in LOWTRAN7 and MODTRAN. Data in this input stream include conversion factors from equivalent water content to aerosol/cloud extinction coefficient and values of aerosol/cloud extinction, absorption and asymmetry parameter versus wavelength for up to four altitude regions. Details about variable definitions and record formats can be found in the manual for LOWTRAN7[1] and MODTRAN.[3]

The *.AER* files must be created off-line by the user because the Card 2D series typically involves many input records. However, the SENTRAN7 package does contain a file named *SAMPLE.AER* which can be used by novice users as a guide to create and debug their own aerosol files. The file, *SAMPLE.AER*, contains wavelength scaling factors for standard aerosols in four altitude regions: (1) rural aerosol at 70% humidity in the boundary layer; (2) tropospheric aerosol at 70% humidity in the free troposphere; (3) background stratospheric aerosol for the stratosphere; and (4) meteoric dust in the upper atmosphere.

The *SAMPLE.AER* file with the SENTRAN7 package can be used to do sensitivity studies for aerosol and cloud scattering as a function of wavelength. To do this, the user must first either set the IHAZE parameter on Card 2 equal to 7 or the ICLD parameter on Card 2 equal to 11. When the Edit Module asks for a filename for the Card 2D series, the user can enter 'sample' or the name of another *.AER* file that they have created. After a filename is specified, the next screen contains a list of input parameters for Card 2D where users can assign their percent perturbations. Note that the Edit Module will scan the contents of the input *.AER* file and only display input parameters for the altitude regions where data are provided.

A.5 Aerosol Phase Functions Data File

Files with *.PHS* extensions represent the Card 3B series in LOWTRAN7 and MODTRAN. Data in this input stream are phase functions for aerosol scattering. Details about variable definitions and record formats can be found in the manual for LOWTRAN7[1] and MODTRAN.[3]

Because the Card 3B series usually invloves many input records, the *.PHS* files must be created off-line by the user. However, the SENTRAN7 package does include a file called *SAMPLE.PHS* which can be used by novice users as a guide to create and debug their own phase function files. For reference, the

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SAMPLE.PHS file contains the phase function of a rural aerosol at 70% humidity and at a wavelength of 0.55 μm.

The *SAMPLE.PHS* file with the SENTRAN7 package can be used as part of sensitivity studies for aerosol and cloud scattering. To do this, the user must first set the IPH parameter on Card 3A1 equal to 2. When the Edit Module asks for a filename for the Card 3B series, the user can type 'sample' or the name of another *.PHS* file that they have created. The Edit Module will read the input *.PHS* file, and the phase function will be included in the LOWTRAN7 and MODTRAN input cards. However, the current version of SENTRAN7 does not allow users to perturb values in the *.PHS* file.

A.6 Random Perturbations Data File

Files with *.RND* extensions are needed to generate correlated and uncorrelated random perturbation profiles when RFLG1=7. These files must be created offline by the user. The first record in these files give the number of layers in (I5) format. The integer value must match the number of layers in the *.PRO* file to be specified in SENTRAN7's Edit Module. Subsequent records in *.RND* files each contain three columns of data in (F10.3,2E10.3) format. The columns represent

1. Altitude in km
2. Layer standard deviation, $\sigma(z)$
3. Layer correlation length, $L(z)$ in km.

These records must be repeated for each layer in the *.PRO* file. Note that the altitude grid in the *.RND* must match the altitude grid in the *.PRO* file. Also, the units of $\sigma(z)$ must be consistent with those for the atmospheric variable to be perturbed.

An example of a *.RND* file is shown in Figure A-1. It is not possible to specify values of $\sigma(z)$ as a percentage. If users want to simulate uncorrelated random perturbation profiles, the values of $L(z)$ must be set to zero.

A.7 LOWTRAN7 and MODTRAN Output Files

The output files, *tape7* and *tape8*, contain LOWTRAN7 and MODTRAN generated data. The information in these two files are copied to the files, *TAPE7.OUT* and *TAPE8.OUT*, respectively, in a format which SENTRAN7 can use to extract data for graphical analysis. The contents of these files depend on the values of IEMSCT, IMULT and NOPRT on Card 1. Details about the contents of these output files and record formats can be found in the manual for LOWTRAN7[1] and MODTRAN.[3]

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```
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  0.000  4.000E+00  1.000E+00
  1.000  4.000E+00  1.000E+00
  2.000  4.000E+00  1.000E+00
  3.000  3.000E+00  2.000E+00
  4.000  3.000E+00  2.000E+00
  5.000  3.000E+00  2.000E+00
  6.000  3.000E+00  2.000E+00
  7.000  3.000E+00  2.000E+00
  8.000  3.000E+00  2.000E+00
  9.000  3.000E+00  2.000E+00
 10.000  3.000E+00  2.000E+00
 11.000  2.000E+00  5.000E+00
 12.000  2.000E+00  5.000E+00
 13.000  2.000E+00  5.000E+00
 14.000  2.000E+00  5.000E+00
 15.000  2.000E+00  5.000E+00
 16.000  2.000E+00  5.000E+00
 17.000  2.000E+00  5.000E+00
 18.000  2.000E+00  5.000E+00
 19.000  2.000E+00  5.000E+00
 20.000  2.000E+00  5.000E+00
 21.000  2.000E+00  5.000E+00
 22.000  2.000E+00  5.000E+00
 23.000  2.000E+00  5.000E+00
 24.000  2.000E+00  5.000E+00
 25.000  2.000E+00  5.000E+00
 30.000  1.000E+00  1.000E+01
 35.000  1.000E+00  1.000E+01
 40.000  1.000E+00  1.000E+01
 45.000  1.000E+00  1.000E+01
 50.000  1.000E+00  1.000E+01
 70.000  1.000E+00  1.000E+01
100.000  1.000E+00  1.000E+01
```

Figure A-1. Example of a *.RND* File. The first, second, and third columns are altitude, $\sigma(z)$, and $L(z)$, repectively. Data in this example were used to impose correlated random perturbations on the temperature profile for a tropical atmosphere (*MODEL1.PRO*)

A.8 Customized Output Files

Files with *.TP6,TP7,TP8* extensions are customized output files from LOW-TRAN7 and MODTRAN. SENTRAN7 creates these three files by means of system copy commands on the *tape6 tape7* and *tape8* output files from LOWTRAN7 and MODTRAN. The root name for these files comes from the root name of the input file (*.INP*). Specifically,

1. *tape6* output is copied to *root name.TP6*

2. *tape7* output is copied to *root name.TP7*

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3. *tape8* output is copied to *root name.TP8*.

If the input file generated by SENTRAN7 for LOWTRAN7 and MODTRAN is named *SPACE.INP*, for example, then the output in *tape6*, *tape7*, and *tape8* output is copied to *SPACE.TP6*, *SPACE.TP7*, and *SPACE.TP8*, respectively. This feature is exercised from the Run Module (see the Users Guide).

A.9 3D Files

3D files are files in raw x, y, z format. Z must be a single valued function of x and y, while x and y must form a semi-regular mesh. That is, the (x,y) data should form a rectangular grid with a z value present for every possible (x,y) combination, but the spacing of the x and y points need not be uniform. These files can be written to disk from within the G&A Module of SENTRAN7. It is worth noting that SENTRAN7 can read any file in x, y, z format which conforms to the specifications above. Thus SENTRAN7's graphing and analysis capabilities are not limited to LOWTRAN7 and MODTRAN data. Another fact worth noting is that 3D files are free of cosmetic data, and are easily exported to more powerful graphics and analysis systems.

A.10 Graphics File

Graphics files consist of special escape sequences and character data, that are interpreted by Tektronix 4010/4014 compatible devices in order to generate hard copy output of SENTRAN7 plots. These files are given a default extension of *.TEK*. A wide variety of devices can interpret TEK files, either by design or via special translating programs. Devices supported include video terminals, laser printers, thermal plotters, pen plotters and dot matrix printers. Thus TEK files offer a convenient means of storing and exchanging graphical representations of data.

A.11 Cosmetic File

Cosmetic files contain "cosmetic" information for 3D files. These cosmetic files are actually screendumps of the G&A command screen, providing information on the data source file, any numerical manipulations which have been performed, the most recent raw x, y, z file (**.3D*) generated, if any, and the most recent graphics file (**.TEK*) generated, among other pieces of information.

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A.12 *SEN.ERR* File

The *SEN.ERR* file is devoted to debugging and temporary storage of information on major absorbers. If the user compiles an input file with the /ERROR option, SENTRAN7 writes all compile time errors to *SEN.ERR* along with the names of major absorbing species and their intervals of activity in the current spectral interval.

A.13 *SEN.LOG* File

The *SEN.LOG* file is a product of SENTRAN7's logging function. This function permits the user to maintain a terse log of his/her SENTRAN7 sessions. SENTRAN7 automatically adds comments, which aid in determining the logical flow that was taken through the program. The user can replace these automatic comments with comments of his/her own. Comments consist of all text within the input string following an apostrophe. For example in the string, **edit 'invoke editor function**, "invoke editor function" is a comment and will be ignored by the program.

Using a verbose style in entering commands will also enhance readability of *SEN.LOG* files. For example the following commands, when typed at the main menu will yield identical results:

3 test/m/e

compile test.inp /mesh/error

Clearly, the second style is much more readable, and is the preferred style when developing a *SEN.LOG* file. These tools are indispensible for developing and debugging input files for batch submissions of SENTRAN7.

A.14 *RANDOM1.DAT* File

The file with the fixed file name *RANDOM1.DAT* contains random perturbation profiles. The first column in *RANDOM1.DAT* is altitude as defined in the *.PRO* file and the other columns are perturbed profiles where the first profile is the reference profile. If a sensitivity study has more than one randomly perturbed atmospheric variable, additional profiles are appended at the bottom of *RANDOM1.DAT*.

SENTRAN7 automatically creates *RANDOM1.DAT* whenever a compile command is issued. Thus, the contents of *RANDOM1.DAT* represent the most recent *.INP* file to be created. The contents of *RANDOM1.DAT* cannot be plotted in SENTRAN7's Graph & Analyze Module. An example of output written to *RANDOM1.DAT* is shown in the Users Guide.

A.15 *RANDOM2.DAT* File

The file with the fixed file name *RANDOM2.DAT* contains a statistical analysis of random perturbation profiles. The statistical analysis of randomly perturbed profiles can be used to decide if the code has matched the desired specification within allowable tolerances. Specifically, SENTRAN7 calculates the mean, standard deviation, percent standard deviation and correlation length of the randomly perturbed profiles as a function of altitude. Note that the reference profile is shown in *RANDOM2.DAT*, but it is not included in the analysis.

SENTRAN7 automatically creates *RANDOM2.DAT* whenever a compile command is issued. Consequently, the contents of *RANDOM2.DAT* represent the most recent *.INP* file to be created. If a sensitivity study has more than one randomly perturbed atmospheric variable, additional analyses are appended at the bottom of *RANDOM2.DAT*. Note that statistical analysis always corresponds to the randomly perturbed profiles in *RANDOM1.DAT*. The contents of *RANDOM2.DAT* cannot be plotted in SENTRAN7's Graph & Analyze Module. An example of output written to *RANDOM2.DAT* is shown in the Users Guide.

A.16 Help File

Another file included with the SENTRAN7 package is a help file, *SENTRAN.HLP*. SENTRAN7 uses this file internally in order to generate its help screens. The user is cautioned against tampering with this help file.

CODE CHANGES TO LOWTRAN7 AND MODTRAN

As noted in Section 3.3, LOWTRAN7 and MODTRAN have been modified slightly in order to run with SENTRAN7. These changes have already been made in the LOWTRAN7 and MODTRAN source codes provided with this distribution (*lowtran7.for* and *modtran.for*, respectively). The changes made are outlined here only for reference.

Figure B-1 shows the changes made to the subroutine TRANS in *lowtran7.for*. Line numbers 8020-8060 and 8180-8210 have been commented out. These lines are indicated with a 'c!' comment symbol in Figure B-1.

Figure B-2 shows the changes made to the subroutine TRANS in *modtran.for*. Line numbers 7350-7390 and 7530-7570 have been commented out. These lines are indicated with a 'c!' comment symbol in Figure B-2. In addition, because the input structure for MODTRAN is slightly different from LOWTRAN7, the subroutines BMDATA and DRIVER in *modtran.for* were modified slightly so that MODTRAN could be run from SENTRAN7. The changes made to subroutines BMDATA and DRIVER are shown in Figures B-3 and B-4, respectively. In the subroutine BMDATA, lines of code have been added and/or modified between line numbers 270 and 290. In the subroutine DRIVER, lines of code have been added and/or modified between line numbers 1090 and 1120 and between line numbers 3780 and 3800.

Figure B-1. Code Changes to the Subroutine TRANS in LOWTRAN7 For Use with SENTRAN7

SUBROUTINE TRANS

```
C                                                                       TRA 7850
C    FOR NO MULTIPLE SCATTERING, CALCULATE BLACK BODY FUNCTION,         TRA 7860
C    AS WELL AS RADIANCE ADDING FOR THERMAL                            TRA 7870
C                                                                       TRA 7880
      BBIK=BBFN(TBBY(IK),V)                                             TRA 7890
C     TLNEW=(TX(9)*TX(10))/(TX(7)*TX(6))                                TRA 7900
C     TSNEW=(TX(7)*TX(6))/TX(10)                                        TRA 7910
      TLNEW= TX(9)                                                      TRA 7920
      DTAU=TLOLD-TLNEW                                                   TRA 7930
      IF(IMULT.EQ.1) DTAU = TOTAL - TX(9)                               TRA 7940
      TOTAL = TX(9)                                                     TRA 7950
      IF(DTAU.LE.0.) DTAU=0.                                            TRA 7960
      IF(IMULT .EQ. 0) THEN                                             TRA 7970
          IF(NOPRNT. EQ. -1) THEN                                       TRA 7980
              WRITE(IPR1,1210) V,AHT(IK),AHT(IK+1),BBIK,DTAU,TLNEW       TRA 7990
 1210         FORMAT(F10.0,2F7.2,1P2E12.5,0PF12.9)                      TRA 8000
          ENDIF                                                         TRA 8010
C    >>>>  CODE MODIFIED BY SPARTA FOR SENTRAN7  <<<<                   
c!       IF (DTAU.LT.1.0E-5.AND.TLNEW.LT.1.0E-5) THEN                   TRA 8020
c!          IF(NOPRNT. EQ. -1) WRITE(IPR1,1220)                         TRA 8030
c! 1220      FORMAT('     -999.',T63,' DTAU   EXIT LOOP ')             TRA 8040
c!          GO TO 220                                                   TRA 8050
c!       ENDIF                                                          TRA 8060
C    >>>>          END MODIFICATIONS           <<<<                    
      SUMV=SUMV+BBIK*DTAU                                               TRA 8070
C    RADIANCE / CONSERVATIVE SCATTERING                                TRA 8080
      ELSE                                                              TRA 8090
      IF(INIT.EQ.0) GO TO 210                                          TRA 8100
      N1 = ML - IMAP(IK) + IOFF                                         TRA 8110
      IF(N1.GE.ML ) N1 = ML - 1                                        TRA*8122
          IF(NOPRNT. EQ. -1) THEN                                      TRA 8130
              N = N1 + 1                                                TRA 8140
              WRITE(IPR1,1230) V,AHT(IK+1),UMB(N),UMBS(N),DMB(N),       TRA 8150
      X         DMBS(N,,SUM*TX(9),TX(9)                                TRA 8160
          ENDIF                                                         TRA 8170
C    >>>>  CODE MODIFIED BY SPARTA FOR SENTRAN7  <<<<                   
c!       IF (DTAU.LT.1.0E-5.AND.TX(9).LT.1.0E-5) THEN                   TRA 8180
c!          IF(NOPRNT. EQ. -1) WRITE(IPR1,1220)                         TRA 8190
c!          GO TO 220                                                   TRA 8200
c!       ENDIF                                                          TRA 8210
C    >>>>          END MODIFICATIONS           <<<<                    
```

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Figure B-2. Code Changes to the Subroutine TRANS in MODTRAN For Use with SENTRAN7

SUBROUTINE TRANS

```
C                                                                       TRA 7200
C     FOR NO MULTIPLE SCATTERING, CALCULATE BLACK BODY FUNCTION,        TRA 7210
C     AS WELL AS RADIANCE ADDING FOR THERMAL                            TRA 7220
C                                                                       TRA 7230
          BBIK=BBFN(TBBY(IKOFF),V)                                      TRA 7240
          TLNEW=TX(9)                                                   TRA 7250
          DTAU=TLOLD-TLNEW                                              TRA 7260
          IF(IMULT.EQ.1)DTAU=TOTAL-TX(9)                                TRA 7270
          TOTAL=TX(9)                                                   TRA 7280
          IF(DTAU.LE.0.)DTAU=0.                                         TRA 7290
          IF(IMULT.EQ.0)THEN                                            TRA 7300
              IF(NOPRNT.EQ.-1)THEN                                      TRA 7310
                  WRITE(IPR1,'(F10.0,2F7.2,1P2E12.5,0PF12.9)')          TRA 7320
     1              V,AHT(IK),AHT(IK+1),BBIK,DTAU,TLNEW                  TRA 7330
              ENDIF                                                     TRA 7340
C     >>>>  CODE MODIFIED BY SPARTA FOR SENTRAN7  <<<<
c!                IF(DTAU.LT.1.E-5 .AND. TLNEW.LT.1.E-5)THEN            TRA 7350
c!                    IF(NOPRNT.EQ.-1)                                  TRA 7360
c!   1                   WRITE(IPR1,'(5X,5H-999.,T65,16HDTAU   EXIT LOOP)') TRA 7370
c!                       GOTO200                                        TRA 7380
c!                ENDIF                                                 TRA 7390
C     >>>>      END MODIFICATIONS            <<<<
              SUMV=SUMV+BBIK*DTAU                                       TRA 7400
C                                                                       TRA 7410
C         RADIANCE / CONSERVATIVE SCATTERING                            TRA 7420
C                                                                       TRA 7430
          ELSE                                                          TRA 7440
              IF(INIT.EQ.0)GOTO190                                      TRA 7450
              N1=ML-IMAP(IK)+IOFF                                       TRA 7460
C     **************** ERRATA JUNE 21 89 NEXT CARD                      TRA*7465
CC            IF(N1.GE.ML)GOTO190                                       TRA*7470
              IF(N1.GE.ML)N1 = ML - 1                                   TRA*7472
C     **************** END ERRATA                                       TRA*7474
              IF(NOPRNT.EQ.-1)THEN                                      TRA 7480
                  N=N1+1                                                TRA 7490
                  WRITE(IPR1,'(F10.0,F7.2,1P5E12.5,0PF10.5)')V,AHT(IK+1) TRA 7500
     1                 ,UMB(N),UMBS(N),DMB(N),DMBS(N),SUM*TX(9),TX(9)   TRA 7510
              ENDIF                                                     TRA 7520
C     >>>>  CODE MODIFIED BY SPARTA FOR SENTRAN7  <<<<
c!                IF(DTAU.LT.1.E-5 .AND. TX(9).LT.1.E-5)THEN            TRA 7530
c!                    IF(NOPRNT.EQ.-1)                                  TRA 7540
c!   1                   WRITE(IPR1,'(5X,5H-999.,T65,16HDTAU   EXIT LOOP)') TRA 7550
c!                       GOTO200                                        TRA 7560
c!                ENDIF                                                 TRA 7570
C     >>>>      END MODIFICATIONS            <<<<
```

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Figure B-3. Code Changes to the Subroutine BMDATA in MODTRAN For Use with SENTRAN7

SUBROUTINE BMDATA

```
C                                                                  BMD   270
C       >>>>  CODE MODIFIED BY SPARTA FOR SENTRAN7   <<<<
        CHARACTER*80 DIRUF
        OPEN(UNIT=60,FILE='MODTRAN.RUN',STATUS='OLD')
        READ(60,'(L1)')MODTRN
        READ(60,'(A80)')DIRUF
        CLOSE(UNIT=60)
        ITB = 9                                                    XXX
        OPEN(ITB,FILE=DIRUF,STATUS='OLD',FORM='UNFORMATTED')       BMDXXX80
C       >>>>           END MODIFICATIONS                 <<<<
     10 REWIND(ITB)                                                BMD   290
```

Figure B-4. Code Changes to the Subroutine DRIVER in MODTRAN For Use with SENTRAN7

SUBROUTINE DRIVER

```
C    1  M4,M5,M6,MDEF,IM,NOPRT,TBOUND,SALB                         DRV  1090
C       >>>>  CODE MODIFIED BY SPARTA FOR SENTRAN7   <<<<
        OPEN(UNIT=60,FILE='MODTRAN.RUN',STATUS='OLD')
        READ(60,'(L1)')MODTRN
        CLOSE(UNIT=60)
        READ(IRD,'(I5,12I5,F8.3,F7.2)')MODEL,ITYPE,IEMSCT,         DRV  1100
     1  IMULT,M1,M2,M3,M4,M5,M6,MDEF,IM,NOPRT,TBOUND,SALB          DRV  1110
C       >>>>           END MODIFICATIONS                 <<<<
 1110 FORMAT(13I5,F8.3,F7.2)                                       DRV  1120


C1401 FORMAT('0 CARD 4   *****',3F10.3)                            DRV  3780
C  >>>>  MODIFICATIONS BY SPARTA FOR SENTRAN7   <<<<
        READ(IRD,'(3F10.3,I10)')RV1,RV2,RDV,IFWHM                  DRV  3790
        IV1=INT(RV1)
        IV2=INT(RV2)
        IDV=INT(RDV)
C  >>>>  END MODIFICATIONS  <<<<
  401 WRITE(IPR,'(15H0 CARD 4   *****,4I10)')IV1,IV2,IDV,IFWHM     DRV  3800
```

There are many commands and files associated with the SENTRAN7 package. Therefore, this appendix serves as a quick reference guide to help users become familiar with operating SENTRAN7. Effectively, the guide is a collection of tables introduced in the main text. The material is not formally organized; rather, it is designed to give users quick and concise information about the commands and features of SENTRAN7. The guide contains information about:

1. Cursor control commands in the Edit Module
2. Perturbation commands in the Edit Module
3. Examples of perturbation commands
4. Allowable compiler commands as typed from the Main Menu
5. Examples of compiler commands as typed from the Main Menu
6. Allowable run commands as typed from the Main Menu
7. Types of available plots in the Graph and Analyze Module
8. Numerical analysis commands in the Graph and Analyze Module
9. Plotting commands in the Graph and Analyze Module
10. I/O and control commands in the Graph and Analyze Module
11. Default file names and extensions with SENTRAN7
12. File checklist for the SENTRAN7 package

The above information is provided in easy-to-use tables on the pages that follow.

Table C-1. List of Cursor Control Commands in the Edit Module of SENTRAN7

COMMAND	ACTION
UP n[1]	Move cursor up n lines
DN n	Move cursor down n lines
PU	Move to previous major[2] card image
PD	Move to next major card image
END	End editing session, goto main menu

[1] n is optional; its absence means $n = 1$
[2] Major cards are Card 1, 2, 3, 4

Table C-2. List of Perturbation Command Syntaxes in the Edit Module

TYPE OF PERTURBATION	SYNTAX FORMAT
%[1]	*nominal value %value*
+/-	*nominal value +/- value*
Iteration	*nominal value [start][2] TO final [STEP n]*
List	*nominal value value2 value3 ...*
Use Previous	*nominal value **
Deterministic[3]	*DET1, DET2*
Random[3]	*RAN1, RAN2*

[1] On Card 2C and 2D, no nominal value allowed with percent perturbation
[2] Terms in "[ ]" are optional
[3] Allowed with Card 2C parameters only

Table C-3. Examples of Perturbation Directives

SAMPLE PARAMETER	PERTUBATION DIRECTIVE	SEQUENCE PRODUCED
H1	5.0 %20	4.0, 5.0, 6.0
H2	8.0 +/- 2	6.0, 8.0, 10.0
ANGLE	45.0 TO 47	45.0, 46.0, 47.0
RANGE	10.0 TO 20 STEP 5	10.0, 15.0, 20.0
VIS	5.0 0 TO 10 STEP 5	0.0, 5.0, 10.0
MODEL	4 3 6	4, 3, 6

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Table C-4. Allowable Compiler Commands As Typed From the Main Menu

```
compile [card image name] [/MESH /NOMESH /ERROR]

                         or

3 [carriage return] [card image name] [/MESH /NOMESH /ERROR]
```

/MESH Generates All Possible Combinations of Perturbed Input Parameters
/NOMESH Perturbs One Parameter at a Time, Holding All Others Fixed
/ERROR Creates *SEN.ERR* Containing Compile Errors and List of Active Molecular Absorbers

Table C-5. Examples of Compiler Commands as Typed From the Main Menu

COMMAND	EFFECT
compile test /m /e	Compiles input file named *TEST.INP* as MESH and generates the error file *SEN.ERR*
3 <RETURN> **test /n**	Compiles input file named *TEST.INP* as NOMESH with no error file
com test.wow	Compiles input file named *TEST.WOW* using last mode (MESH or NOMESH) as default, no error file generated
c test.dumb /m /n /e	Compiles input file named *TEST.DUMB* as NOMESH demonstrating that MESH and NOMESH are exclusive, with NOMESH taking precedence. An error file is created

Table C-6. Allowable Run Commands As Typed From the Main Menu

```
run [input file name] [/s /n]

              or

6 [carriage return] [input file name] [/s /n]
```

/s Saves LOWTRAN and MODTRAN Output Files as Customized File Names
/n Deactivates the Save Output Files Option

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Table C-7. Type of Plots Available in the Graph and Analyze Module

PLOT TYPE	SPECIFIC PLOTS	PARAMETERS
Raw x, y, z		
Transmittance	Total Transmittance Log of Total Transmittance Uniform Mixed Gases Trace Gases Molecular Scattering H_2O H_2O Continuum Ozone (O_3) N_2 Continuum Aerosol and Hydrometeor CO_2 CO CH_4 N_2O O_2 NH_3 NO NO_2 SO_2 HNO_3 Aerosol and Hydrometeor Absorption	IEMSCT = 0 IMULT = 0
Atmospheric Radiance	Total Transmittance Radiance Log of Total Transmittance	IEMSCT = 1 IMULT = 0,1
Differential Transmittance	DTAU DTAU / Layer Thickness	IEMSCT = 1,2 IMULT = 0 NOPRT = -1
Black Body Function	DTAU * Black Body Function (DTAU * Black Body Function) / Layer Thickness	IEMSCT = 1,2 IMULT = 0 NOPRT = -1
Fluxes/Irradiance	Upward Total FLUX Upward Solar FLUX Downward Total FLUX Downward Solar FLUX Direct Solar Irradiance	IEMSCT = 1,2 IMULT = 1 NOPRT = -1
Solar/Lunar Radiance	Total Transmittance Radiance Path Scattered Single Scattered Total Ground Reflectance Direct Reflected Total Radiance Log of Total Transmittance	IEMSCT = 2 IMULT = 0,1
Direct Solar Radiance	Total Transmittance Transmitted Solar Incident Solar Log of Total Transmittance	IEMSCT = 3 IMULT = 0

Table C-8. List of Numerical Commands in Graph and Analyze Module

COMMAND	ARGUMENTS	DESCRIPTION
A2T	NONE	Optical Depth to Transmittance Transformation Transform z axis according to $z=\exp(-z)$
DX	NONE	Compute partial derivative of the data set with respect to the x axis
DY	NONE	Compute partial derivative of the data set with respect to the y axis
DDX	NONE	Compute second partial derivative of the data set with respect to the x axis
DDY	NONE	Compute second partial derivative of the data set with respect to the y axis
DYDX	NONE	Compute cross derivative of the data set with respect to the y axis and then the x axis
DXDY	NONE	Compute cross derivative of the data set with respect to the x axis and then the y axis
LOG	[X][Y][Z]	Transform all coordinates of the named axis to their log values (Example: 'log x')
MAXIMUM	NONE	Write the maximal z values on the screen along with their x,y coordinates
MEAN	NONE	Compute and displays the mean z axis value
MINIMUM	NONE	Write the minimal z values on the screen along with their x,y coordinates
NOSORT	[X][Y]	Suppress SENTRAN's tendency to sort data into increasing order (Example: 'nosort x')
SWAP	NONE	Swap the x and y axes
T2A	NONE	Transmittance to Optical Depth Transformation Transform z axis according to $z=\log(1/z)$

Table C-9. List of Plotting Commands in Graph and Analyze Module

COMMAND	ARGUMENTS	DESCRIPTION
PLOT	[file name][VT240]	Plot the data set to the specified file name (*.TEK) or to the screen [VT240 argument] (NOTE: Both arguments may be specified and the program will plot the data to the file and to the screen)
TITLE	[plot title]	Treat all following text as title for next plot, and center this text at the top of the plot
XLABEL	[x axis Label]	Treat all following text as the x axis label (up to 30 characters)
YLABEL	[y axis Label]	Treat all following text as the y axis label (up to 30 characters)
ZLABEL	[z axis Label]	Treat all following text as the z axis label (up to 30 characters)

Table C-10. List of I/O and Control Commands in Graph and Analyze Module

COMMAND	ARGUMENTS	DESCRIPTION
WRITE	[x, y, z file name]	Write the current data set to the named file as raw x, y, z data (default extension is .3D)
COSMETIC	[file name]	Screendump of current G&A command screen to the named file
NEW	NONE	Restart the G&A Module
EXIT	NONE	Exit the G&A Module, return to Main Menu
HELP	[command name]	Accesses the G&A on-line help utility. If a valid G&A command is supplied as an argument, then help on the selected command is provided. If no argument is supplied, then a special introductory HELP screen is presented, listing all of the G&A commands.
REFRESH	NONE	Redraw the G&A command screen

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Table C-11. Default File Names Associated With SENTRAN7

FILE NAME AND EXTENSION	ORIGIN	CONTENTS
*.MTH	SENTRAN7	Methodology files
*.INP	SENTRAN7	LOWTRAN7/MODTRAN input files
*.PRO	User	Model atmosphere data (*i.e.*, Card 2C series)
*.AER	User	Aerosol extinction coefficients (*i.e.*, Card 2D series)
*.PHS	User	Aerosol phase functions (*i.e.*, Card 3B series)
*.RND	User	Layer standard deviations and correlation lengths for random perturbations
*.OUT	LOWTRAN7/MODTRAN	Output data used for plotting
*.TP6,TP7,TP8	SENTRAN7	Customized output data files from LOWTRAN/MODTRAN
*.3D	User/SENTRAN7	Raw x, y, z data
*.TEK	SENTRAN7	Tektronix graphics files
*.COS	SENTRAN7	Cosmetic data
SEN.ERR	SENTRAN7	Error log and major absorber infomation
SEN.LOG	SENTRAN7	User input log
RANDOM1.DAT	SENTRAN7	Tabulated random perturbation profiles
RANDOM2.DAT	SENTRAN7	Statistical analysis of random perturbation profiles

* is a wildcard indicating arbitrary text

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Table C-12. File Checklist for SENTRAN7. File listing is for UNIX systems. Users must change "*.f" extensions to "*.for" for VAX/VMS systems

FILE NAME	CONTENTS
senmain.f	Source code for SENTRAN7 (main program only)
sensubs.f	Source code for SENTRAN7 (supporting routines)
senpert.f	Source code for SENTRAN7 (perturbation routines)
senchk.f	Source code for SENTRAN7 (error checking routines)
senvms.for	Source code for SENTRAN7 (VAX computer systems only)
senunix.f	Source code for SENTRAN7 (UNIX computer systems only)
andor.c	Fortran bit manipulation code (UNIX computer systems only)
MAJABS.DAT	Data file defining regions of molecular absorption
DIRECT.ORY	Configuration file containing directory and name of LOWTRAN7 and MODTRAN executables and the *UFTAPE.DAT* file. Current directory is assumed when *DIRECT.ORY* does not exist
SENTRAN.HLP	SENTRAN7 on-line help utility file
MODEL1.PRO	Tropical atmosphere profile (*i.e.*, Card 2C series)
MODEL2.PRO	Midlatitude summer profile
MODEL3.PRO	Midlatitude winter profile
MODEL4.PRO	Subarctic summer profile
MODEL5.PRO	Subarctic winter profile
MODEL6.PRO	U.S. standard profile
SAMPLE.AER	Sample Card 2D series: normalized aerosol extinction versus wavelength for four aerosol regions
SAMPLE.PHS	Sample Card 3B series: aerosol phase functions for four aerosol regions
SAMPLE.RND	Sample random perturbations input file
DEFAULT.MTH	Sample methodology file (used in Tutorial #1)
lowtran7.f	Source code for LOWTRAN7
modtran.f	Source code for MODTRAN
mkbin.f	Program creates *UFTAPE.DAT* from *BMTAPE.DAT*
makefile.com	Command file for compiling and linking SENTRAN7 on VAX/VMS systems. Type '@makefile' to execute
makefile	Unix command file for compiling and linking SENTRAN7 on SUN systems. Type make to execute

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Figure D-1 outlines the logical flow for selecting the plotting parameters in the Graph and Analyze Module of SENTRAN7. Note that if the user has chosen to plot a raw x, y, z data file, the Graph and Analyze Module will immediately prompt the user for the name of the file. This file is then read in and the command screen is presented to the user for entering commands to manipulate and plot the data set. If the user is plotting differential transmittance (DTAU), black body functions or fluxes/irradiance, the x and y axes are automatically set to layer # and wavenumber, respectively. The user then selects the z axis parameter to plot and enters a LOWTRAN7 *tape8* type file to be read in. For all other plot types, the user selects the parameters to be plotted on the x, y and z axes, according to the flow diagram in Figure D-1. The user is referred to Section 4.2.8 for more information on the Graph and Analyze Module of SENTRAN7.
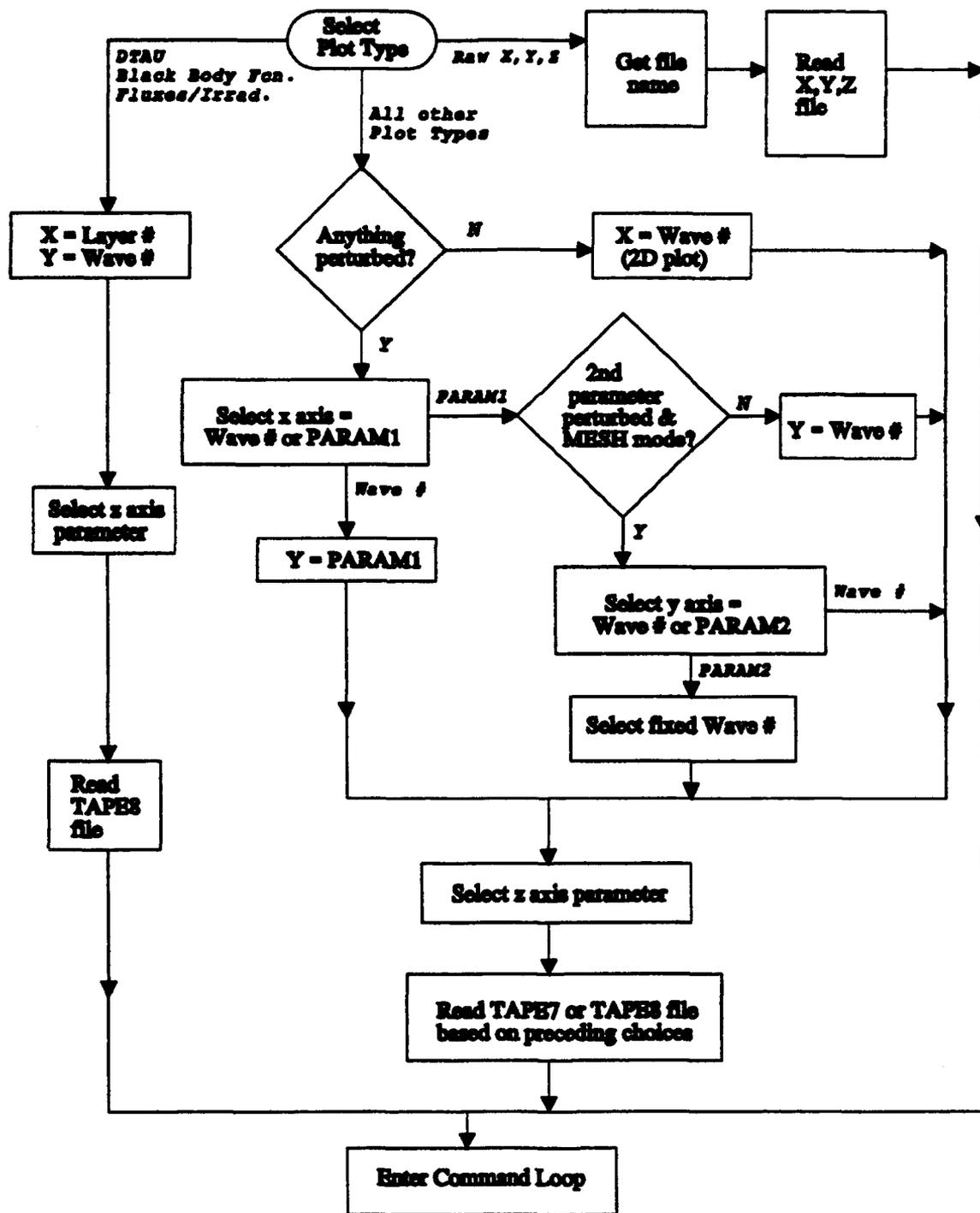
Figure D-1. Simplified Flow Diagram for Selecting Plotting Parameters in the Graph and Analyze Module. PARAM1 and PARAM2 represent the first and second LOWTRAN7 variables perturbed

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