UNCLASSIFIED
SECURITY CLASSIFICATION OF THIS PAGE

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1a. REPORT SECURITY CLASSIFICATION: UNCLASSIFIED

1b. RESTRICTIVE MARKINGS:

AD-A211 484

...EDULE

...MBER(S)

3. DISTRIBUTION/AVAILABILITY OF REPORT: Approved for public release; Distribution is unlimited

(2)

5. MONITORING ORGANIZATION REPORT NUMBER(S): AFOSR-TR- 89-1056

6a. NAME OF PERFORMING ORGANIZATION: Pennsylvania State University

6b. OFFICE SYMBOL (If applicable):

7a. NAME OF MONITORING ORGANIZATION: AFOSR/NC

6c. ADDRESS (City, State, and ZIP Code):
Department of Electrical Engineering
University Park, PA 16802

7b. ADDRESS (City, State, and ZIP Code):
Building 410
Bolling AFB, DC 20332-6448

8a. NAME OF FUNDING/SPONSORING ORGANIZATION: AFOSR

8b. OFFICE SYMBOL (If applicable): NC

9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER: F49620-87-C-0057

8c. ADDRESS (City, State, and ZIP Code):
Building 410
Bolling AFB, DC 20332-6448

10. SOURCE OF FUNDING NUMBERS

PROGRAM ELEMENT NO.	PROJECT NO.	TASK NO	WORK UNIT ACCESSION NO.
61102F	2310	A1	

11. TITLE (Include Security Classification): Sensitivity Evaluation Plan for Lowtran

12. PERSONAL AUTHOR(S): Ken Tomiyama, and Michael Hogan

13a. TYPE OF REPORT	13b. TIME COVERED	14. DATE OF REPORT (Year, Month, Day)	15. PAGE COUNT
FINAL	FROM ____ TO ____	August 28, 1988	106

16. SUPPLEMENTARY NOTATION:

17. COSATI CODES

FIELD	GROUP	SUB-GROUP

18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number):

19. ABSTRACT (Continue on reverse if necessary and identify by block number)

See Back

20. DISTRIBUTION/AVAILABILITY OF ABSTRACT: ☐ UNCLASSIFIED/UNLIMITED ☐ SAME AS RPT. ☐ DTIC USERS

21. ABSTRACT SECURITY CLASSIFICATION: UNCLASSIFIED

22a. NAME OF RESPONSIBLE INDIVIDUAL: Lt Col James G. Stobie

22b. TELEPHONE (Include Area Code): (202) 767-4963

22c. OFFICE SYMBOL: AFOSR/NC

DD Form 1473, JUN 86 *Previous editions are obsolete.*

SECURITY CLASSIFICATION OF THIS PAGE
UNCLASSIFIED

89 8 10 064

19. The computer code LOWTRAN, developed by the Air Force Geophysics Laboratory, computes transmittance and radiance for given climatological conditions and path geometries over given spectral regions within 250 to 40,000 cm-1. Naturally, usefulness of its output is determined by the accuracy of the input variables. Input climatological conditions should be specified as accurately as possible for successful utilization of LOWTRAN results. However, atmospheric variables are inherently difficult to specify with high accuracy due to their significant variability. Therefore, it is critical to evaluate the affects of input uncertainties on the output accuracy, in other words, the sensitivity of LOWTRAN outputs to input variations. This requires a complication of numerous LOWTRAN computations and an appropriate method of presenting the sensitivity. We have developed a computer code, called SENTRAN, for this particular task. It automates the process of LOWTRAN sensitivity analysis by providing various capabilities such as: fail-safe interactive input session, automatic generation of LOWTRAN input deck sets with perturbed values for multiple input parameters, autonomous post-processing of TAPE7 outputs including data extraction and partial derivative evaluation, and graphical representation of the outputs in both 2D and 3D formats. SENTRAN is so versatile that its usefulness is not limited to the sensitivity analysis. It can provide extremely fast turn-around time for any other LOWTRAN analysis.

Final Report

SENSITIVITY EVALUATION PLAN FOR LOWTRAN

Submitted to

The Air Force Office of Scientific Research
Bolling Air Force Base
Washington, D.C.

Contract Number

F49620-87-C-0057

Submitted by

Ken Tomiyama, Assistant Professor
Michael Hogan, Graduate Assistant
Department of Electrical Engineering
Pennsylvania State University
University Park, Pennsylvania 16802
(814) 865-7667

August 28, 1988

ABSTRACT

The computer code LOWTRAN, developed by the Air Force Geophysics Laboratory, computes transmittance and radiance for given climatological conditions and path geometries over given spectral regions within 350 to 40,000 cm^{-1}. Naturally, usefulness of its output is determined by the accuracy of the input variables. Input climatological conditions should be specified as accurate as possible for successful utilization of LOWTRAN results. However, atmospheric variables are inherently difficult to specify with high accuracy due to their significant variability. Therefore, it is critical to evaluate the effects of input uncertainties on the output accuracy, in other words, the sensitivity of LOWTRAN outputs to input variations. This requires a compilation of numerous LOWTRAN computations and an appropriate method of presenting the sensitivity. We have developed a computer code, called SENTRAN, for this particular task. It automates the process of LOWTRAN sensitivity analysis by providing various capabilities such as: fail-safe interactive input session, automatic generation of LOWTRAN input deck sets with perturbed values for multiple input parameters, autonomous post-processing of TAPE7 outputs including data extraction and partial derivative evaluation, and graphical representation of the outputs in both 2D and 3D formats. SENTRAN is so versatile that its usefulness is not limited to the sensitivity analysis. It can provide extremely fast turn-around time for any other LOWTRAN analysis.

TABLE OF CONTENTS

LIST OF FIGURES

1. Introduction

1.1 Background

LOWTRAN, (Kneizys et al. 1980, Kneizys et al. 1983) is a computer code which evaluates atmospheric transmittance and radiance for given climatological conditions and frequency regions at moderate spectral resolution. It is widely used for studies of atmospheric propagation of electromagnetic waves in infrared. For example, it is utilized in the Tactical Decision Aid (TDA) (Tomiyama, 1986) to evaluate atmospheric effects on target acquisition and lock-on ranges for infrared detectors.

An important key to a successful utilization of LOWTRAN is the accuracy of the input climatological data. In order for the LOWTRAN output to be useful, the corresponding input must be accurate. For example, transmission of infrared radiation can be severely decreased if there exist cirrus clouds in the optical path. LOWTRAN must be instructed to compute the effect of cirrus cloud and must be given the cloud's characteristic data. Furthermore, if predicted weather conditions have to be used, every effort should be made to obtain accurate forecasts.

Despite the importance of accurate input data, some of the 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 LOWTRAN computations should be critically evaluated if the LOWTRAN results should be meaningful and reliable.

Thus, it was proposed to develop a systematic sensitivity analysis plan for LOWTRAN. The plan is to quantitatively as well as qualitatively evaluate variations in transmittances and radiances computed by LOWTRAN against perturbations in input climatological conditions. Initial effort was spent on determining the optimal method of presenting the sensitivity. Literature on sensitivity were searched for presentation methods (for example, Brayton and Spence 1980, Radonovic 1966, Lakshmanan 1977, and Hu 1981). The plan evolved eventually into a computer software, called SENTRAN (SENsitivity analysis plan for lowTRAN). The capability of SENTRAN greatly exceeded the originally conceived specifications for the sensitivity plan, in that it's usefulness is not limited to the sensitivity analysis. It has become apparent that SENTRAN can revolutionize the way in which LOWTRAN is used and the scope of analyses which can be performed.

1.2 SENTRAN Capabilities

Software realization of the plan must be user friendly and efficient to facilitate the extensive data generation which is needed for sensitivity analysis. This immediately calls for a versatile interactive input capability, in addition to the capability of autonomous LOWTRAN input deck compilation. It also implies an on-line help utility which can lead the user through SENTRAN computation.

Another important requirement is the ease of post-processing of LOWTRAN outputs. SENTRAN tries to isolate LOWTRAN from the user as much as possible so that the user need not be aggravated by book-keeping. It can extract transmittance and/or radiance data from the LOWTRAN output file. It is intelligent enough to prompt the user with the list of input parameters which can be chosen as independent variables for plotting and derivative computation.

It is also required to make SENTRAN widely available. This implies making SENTRAN as machine independent as possible. The interactive part of software considered here may be developed by using, for example, a shell script under UNIX operating system. However, such software is too restrictive since it is operating system dependent. Its application is limited to UNIX based computers only. Therefore, it was decide that SENTRAN be written entirely in FORTRAN-77 language (for example, AT&T 1986), one of the most portable computer languages commonly available.

In early discussions with the contract monitor, it was decided that layer-wise absorption contributions for multi-layer geometry cases has a major importance for sensitivity studies. Therefore, it was decided to include a capability in SENTRAN of extracting this information from LOWTRAN. The quantity which contain this information is an intermediate variable, called DTAU, which is calculated when the radiance computation is activated. Although modification of LOWTRAN was not desirable, a set of small changes were made to output DTAU to a file. Another modification to LOWTRAN is the addition of input and output file naming capability. With this capability, all the files associated with a particular analysis can be identified by the same name with a different extension, such as CASE1.INP and CASE1.OUT for input and output files for 'CASE1' analysis. This enables SENTRAN to properly extract necessary information for post processing. The necessary modifications for LOWTRAN are summarized in Appendix A. SENTRAN will be made available together with the modified LOWTRAN in order to eliminate the need for users to modify their version of LOWTRAN.

SENTRAN's interactive input capabilities rely on sophisticated screen control through ANSI terminal control codes (Digital Equipments Corporation 1984). For its graphics capabilities, SENTRAN chooses TEKTRONIX-4010 (Digital Equipments Corporation 1984, Chapter 6) as the standard, because TEKTRONIX-4010 is probably the most popular graphics format to be emulated. SENTRAN is, by coincidence, optimized for Digital Equipment Corporation's VT240 terminal, because it has both ANSI standard terminal control and TEKTRONIX-4010 emulation capabilities. It is noted that the VT240 is, in fact, one of the industry standard graphics terminals and that this endorses SENTRAN's choice of standards. Furthermore, SENTRAN contains all the graphics routines so that the user is not required to have any additional graphics software to obtain 2D and 3D plots.

Finally, SENTRAN has many useful analysis tools such as evaluating partial derivatives of a variable represented by z-axis with respect to two independent variables given by x- and y-axes. Since the differentiation probably is the most useful and most used in sensitivity analysis, it should be computed in minimum time. For this, we adopted cubic spline technique. The result was an awfully fast derivative evaluation in both x and y directions. The details are presented in the Technical Reference Manual.

1.3 Organization of the Report

The major part of this final report consists of three chapters and three appendices. Detailed description of SENTRAN is divided into two categories and summarized in two manuals entitled; SENTRAN Users Guide & Tutorial, and SENTRAN Technical Reference manual. They are written as independent documents and included in this report as Appendices B, and C, respectively. This format was chosen so that each Appendix can be used as independent manuals as titled. SENTRAN Programmers Guide, which helps those users who need to modify SENTRAN, will also be prepared as a separate document.[1]

Capabilities of SENTRAN are demonstrated in Chapter 2. Comparative analyses in LOWTRAN-5 report (Kneizys et al. 1980), including the sensitivity analysis, are reproduced here using SENTRAN. 3D plotting is used in many cases to exhibit graphical capability of SENTRAN.

Conclusion and suggestions for further research are summarized in Chapter 3.

---

[1] This manual will be submitted to the contract monitor as a special report at a later date.

2. Case Studies

2.1 Introduction

In this chapter, SENTRAN's capabilities are demonstrated through several examples, some of which are selected from the LOWTRAN-5 report (Kneizys et al. 1980). Discussion in this chapter will be focused on the GRAPH & ANALYZE portion of SENTRAN. Other capabilities, especially those of the EDITOR, are fully discussed in SENTRAN Users Guide & Tutorial in Appendix B. The chosen test cases are discussed and their results are summarized in the next section.

2.2 Test Cases

The first several sets of test cases are based on examples in the LOWTRAN-5 report and marked as such. The input conditions were chosen to simulate those of the sample cases discussed in Section 10 as well as those in Section 12 (sensitivity analysis). More examples are provided to show other SENTRAN capabilities which are not used in the LOWTRAN-5 cases. These examples are discussed after LOWTRAN-5 cases.

The figures associated with test cases are placed together at the end of this chapter.

CASE 1. [Based on Figure 28 on pp. 111-112]

Transmittances for a vertical path looking to space from ground with IHAZE = 1 (the Rural aerosol model at 23 km visibility) and for the six atmospheric models over 400 to

2,000 cm^{-1} spectral region at 5 cm^{-1} intervals. The SENTRAN result is summarized in two 3D plots shown in Figures 1-a and 1-b. Two figures differ in the viewing angle as noted in the figure. Note that the Y-axis represents atmospheric model, a discrete parameter.[2] Also a 3D plot of the radiance for the same condition is obtained from SENTRAN and is shown in Figure 1-c.

CASE 2. [Based on Figure 31 on p. 117]

Transmittances for vertical paths looking to space from various altitudes (0 to 40 km at 2 km intervals) with MODEL = 6 (the U.S. Standard atmospheric model) and IHAZE = 1 (the Rural aerosol model at default visibility of 23 km for lower altitudes) over 400 to 4,000 cm^{-1} spectral region at 20 cm^{-1} intervals. The SENTRAN result is in Figure 2-a. Again a 3D plot of radiance is obtained from SENTRAN and is shown in Figure 2-b.

CASE 3. [Based on Figures 47, 48 & 49 on pp. 136-137]

Transmittances and partial derivatives of transmittance with respect to the water vapor density and visibility are obtained for 2 km path at sea level with MODEL = 6 (the U.S. Standard atmospheric model), IHAZE = 2 (the Rural aerosol model at default visibility of 5 km for lower altitudes),

---

[2] It is noted that the transmittance towards the edge of this spectral region does not match that of the figure in LOWTRAN-5 report due to the use of updated water vapor continuum model in LOWTRAN-6.

and VIS = 4 (4 km visibility) over 500 to 3,000 cm^{-1} spectral region at 10 cm^{-1} intervals. Note that perturbations in water vapor density and visibility are needed to compute partial derivatives. The visibility can easily be perturbed by providing perturbation directives. The water vapor density cannot be perturbed easily since it is a variable in the LOWTRAN model atmosphere. The perturbation for this can be achieved by supplying the LOWTRAN model atmosphere as external model (MODEL = 7, and IM = 1). The LOWTRAN models were extracted for this purpose and are available within the SENTRAN package. SENTRAN has a provision of adding percentage perturbation in any of the variables in those models. Alternatively, the perturbation can be realized by using alternate CARD3, since the path considered here is horizontal. The SENTRAN results are plotted in Figures 3-a, 3-b and 3-c.

The following three cases are not based on the LOWTRAN-5 report but included here to show a different sensitivity analysis which can easily be performed with SENTRAN.

CASE 4. Transmittances for horizontal paths with various optical ranges (1 to 10 km) located in layers of several altitudes (0 to 20 km) at a selected wavenumber of 1,300 cm^{-1} with MODEL = 6 and IHAZE = 1. The result is shown in Figure 4.

CASE 5. Same as CASE 4, except that the altitude is fixed at 1 km and for spectral region of 1,000 to 3,000 cm^{-1} at 5 cm^{-1} intervals. The result is shown in Figure 5.

CASE 6. Same as CASE 4, except that the optical range is fixed at 10 km length and for spectral region of 1,000 to 3,000 cm^{-1} at 5 cm^{-1} intervals. The result is shown in Figure 6.

The above three cases were done in a single SENTRAN session, which has two simultaneous perturbations in range and altitude. Note that the LOWTRAN output data set for this case is rather massive even for moderate increments for both ranges and altitudes. For example, 1 km increments for both implies 210 LOWTRAN executions. At 5 cm^{-1} wavenumber intervals, it resulted in more than 18K blocks (512 Bytes per block, hence approximately 9.2 MEG bytes!) of data. SENTRAN's house-keeping capabilities were thoroughly exercised in this analysis.

The following case is to show two ways to plot 2D graphs with SENTRAN. The first and obvious case is when no perturbations are given in the input. This automatically activates SENTRAN's 2D plotting capability, providing a means of single curve cases. The second way is to use SENTRAN's 3D plotting capability with both rotation angles at 0 degrees. This method can be used for multiple curve cases. It is noted, however, that the hidden-line algorithm used in SENTRAN will hide any line which falls behind another line.

CASE 7. Same as the CASE 1 with transmittance calculation. As shown in Figure 7-a, 0 degree is used for both rotations in plotting. The U.S. Standard atmosphere case is chosen for 2D plotting test case and is shown separately in Figure 7-b.

The layer-wise absorption contributions given by DTAU are extracted in the following example.

CASE 8. The same input conditions as CASE 1 is used with a vertical path from 0 to 32 km altitudes. It is noted that the input parameter IEMSCT has to be set either 1 or 2 to activate DTAU computation. The result in 3D plot is shown in Figure 8.

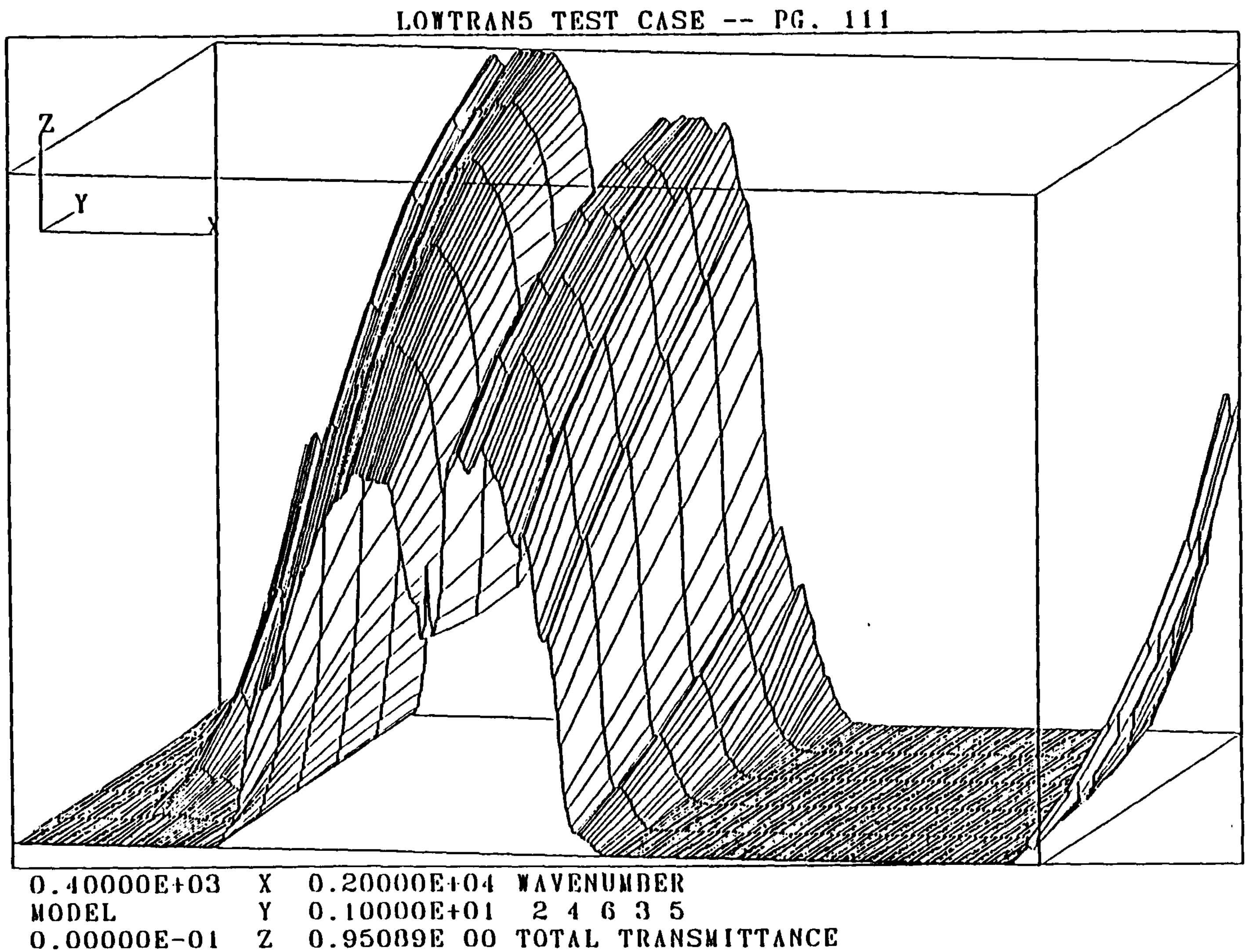


Figure 1-a. Transmittance for vertical path from ground to space for CASE 1. Three axes are as marked in the figure. The viewing angles are -11.25° and 11.25°.

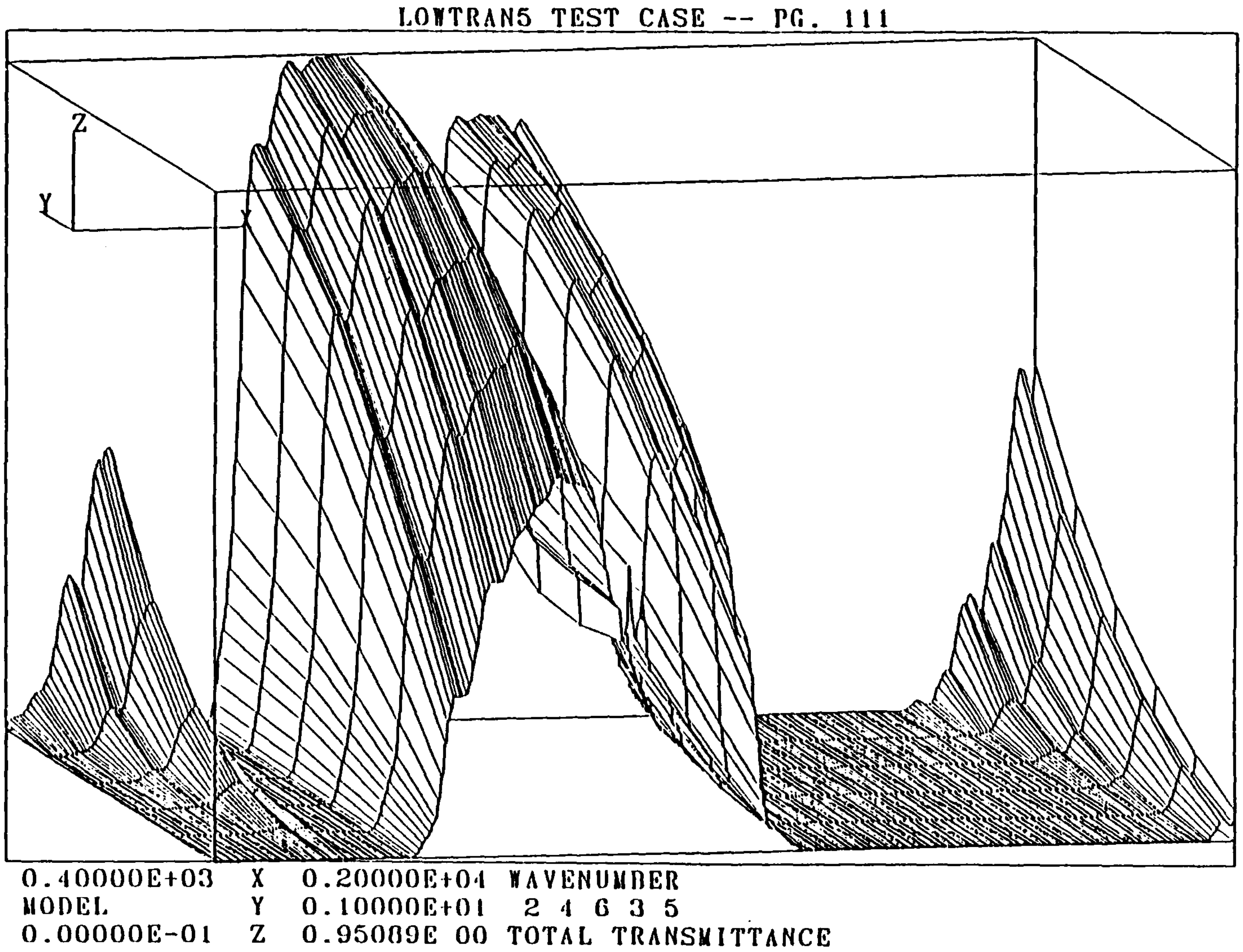


Figure 1-b. Same as Figure 1-a, except the viewing angles. They are both 11.25° here.

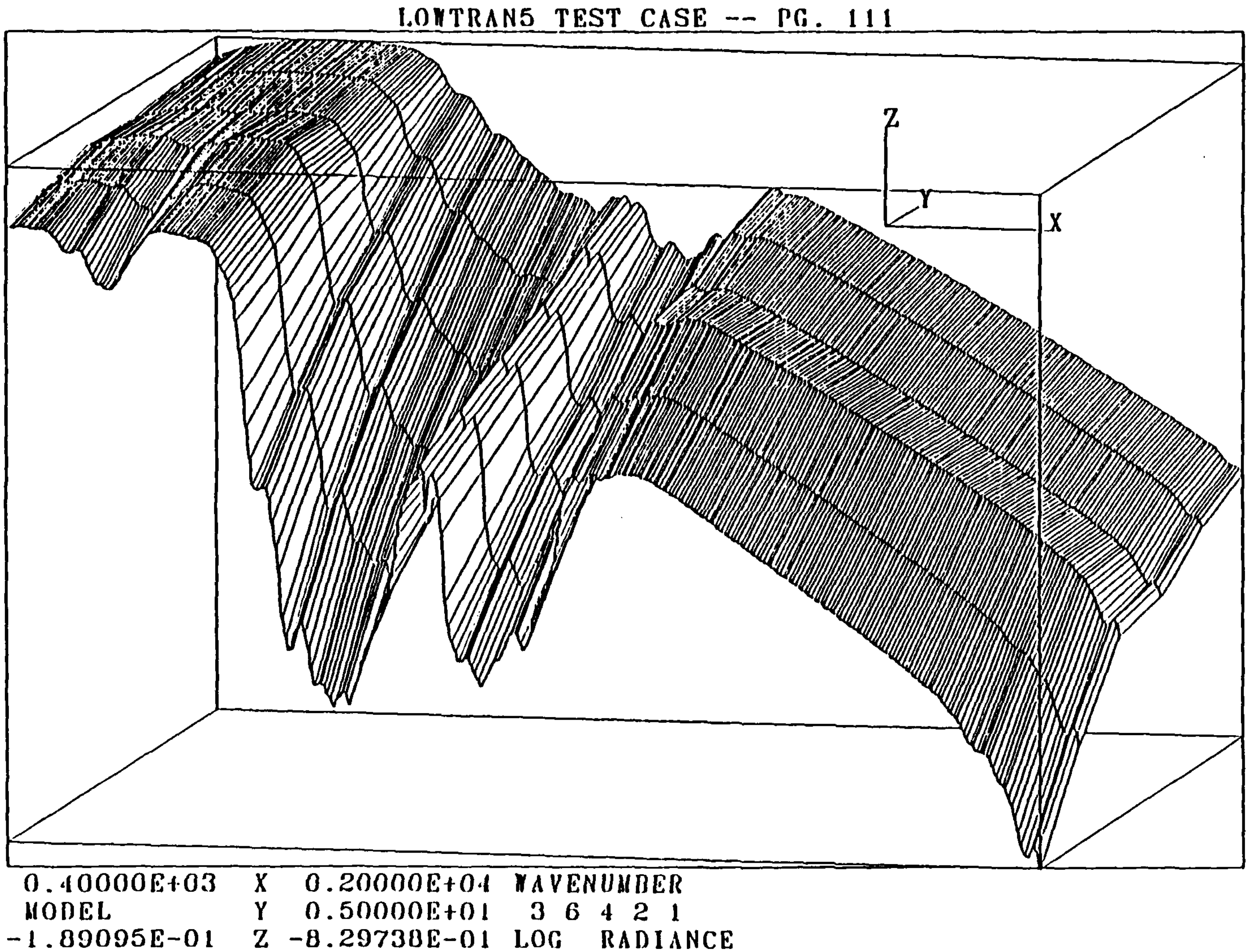


Figure 1-c. Radiance for vertical path from ground to space for CASE 1. Three axes are as marked in the figure. The viewing angles are -11.25° and 11.25°.

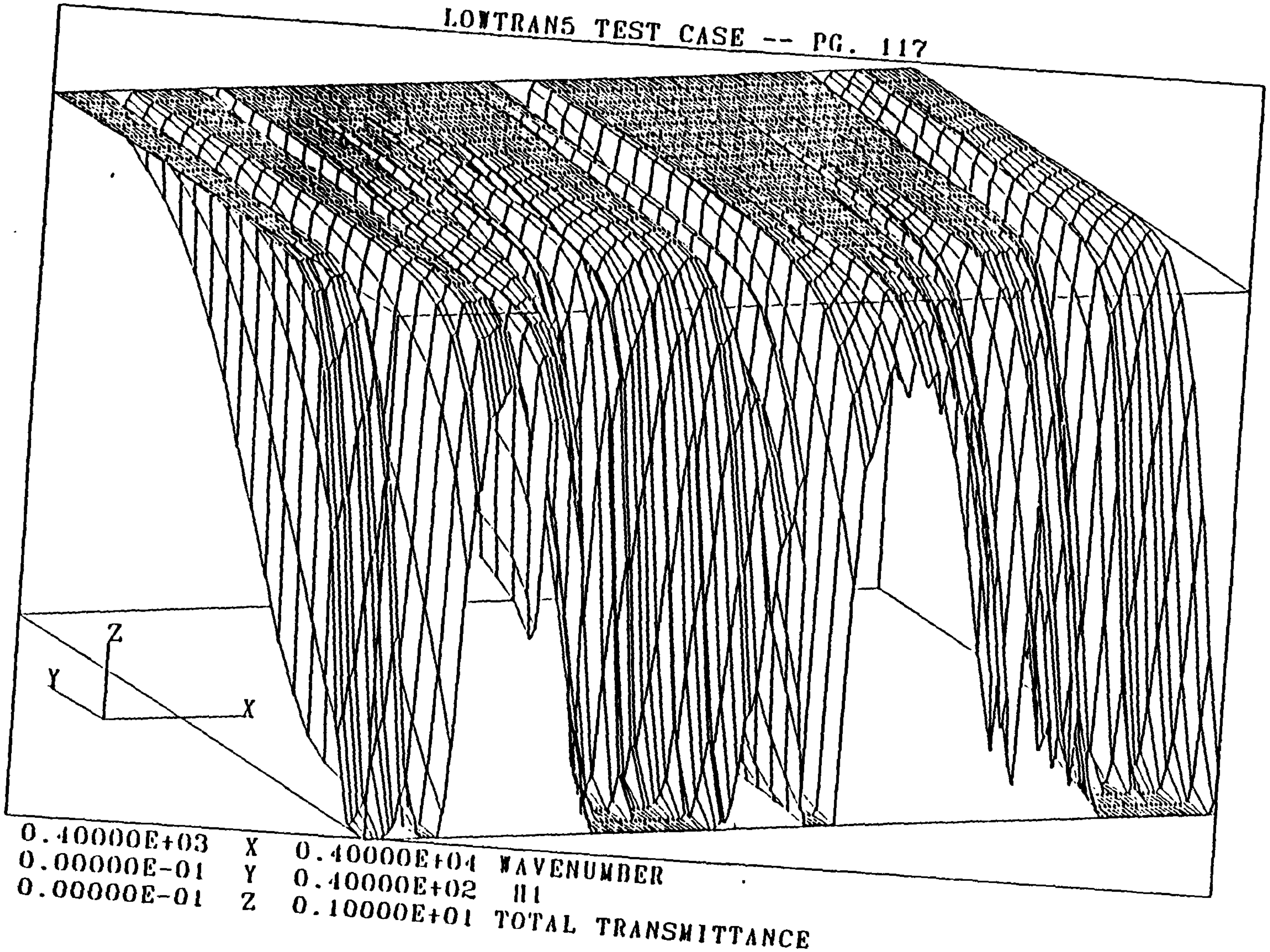


Figure 2-a. Transmittance for vertical path from various altitudes to space for CASE 2. Three axes are as marked in the figure. The viewing angles are -11.25° and 11.25°.

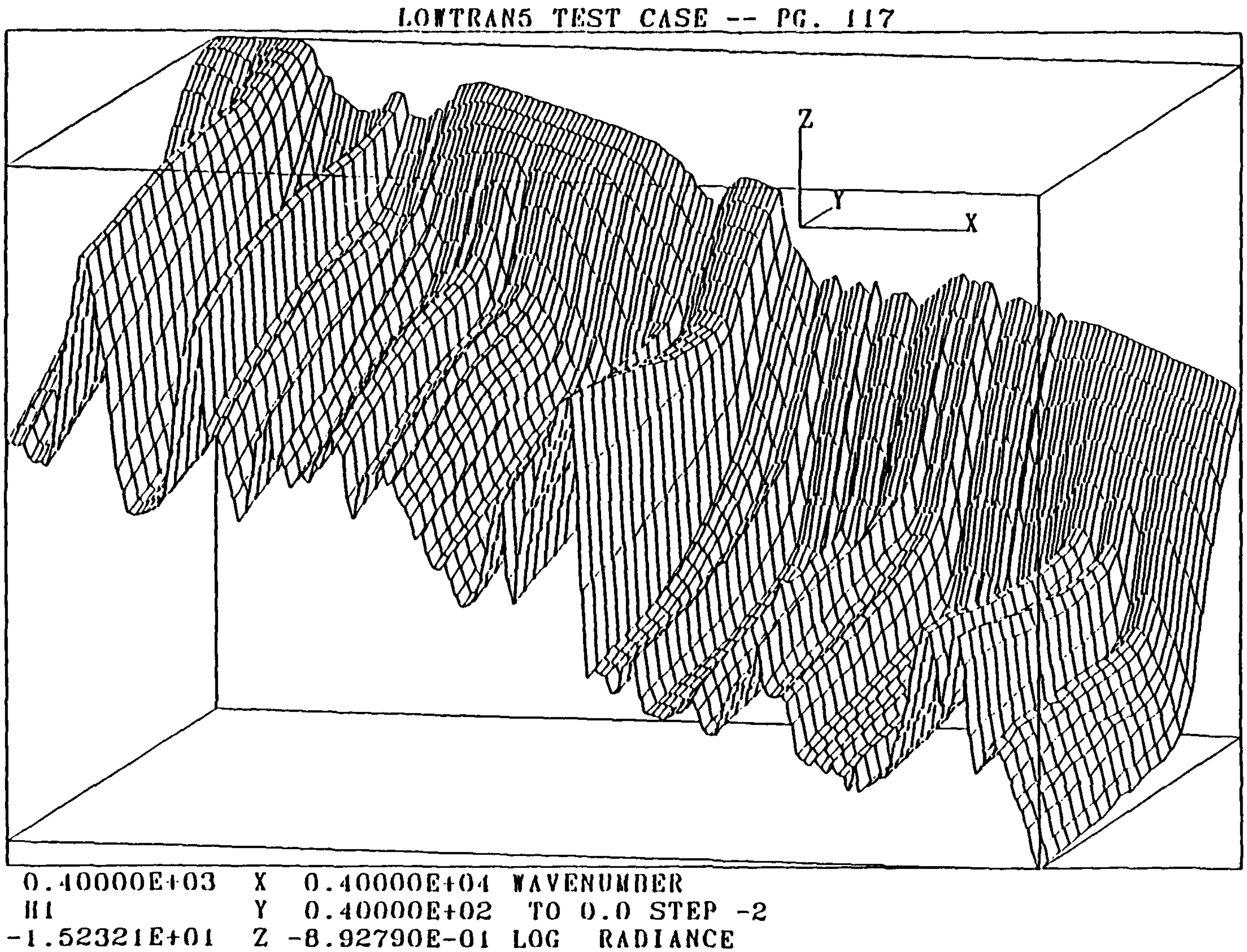


Figure 2-b. Radiance for vertical path from various altitudes to space for CASE 2. Three axes are as marked in the figure. The viewing angles are -11.25° and 11.25°.

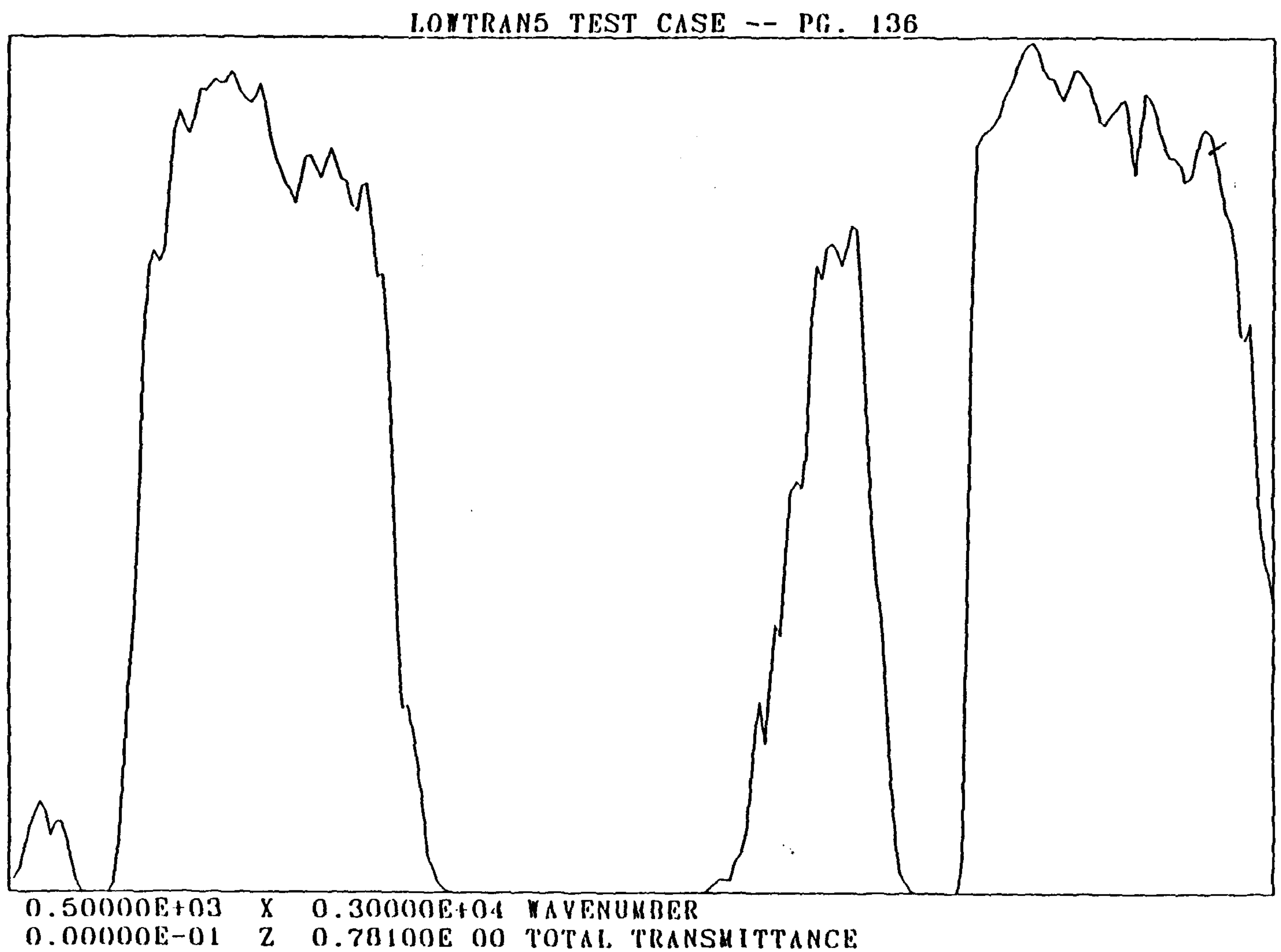
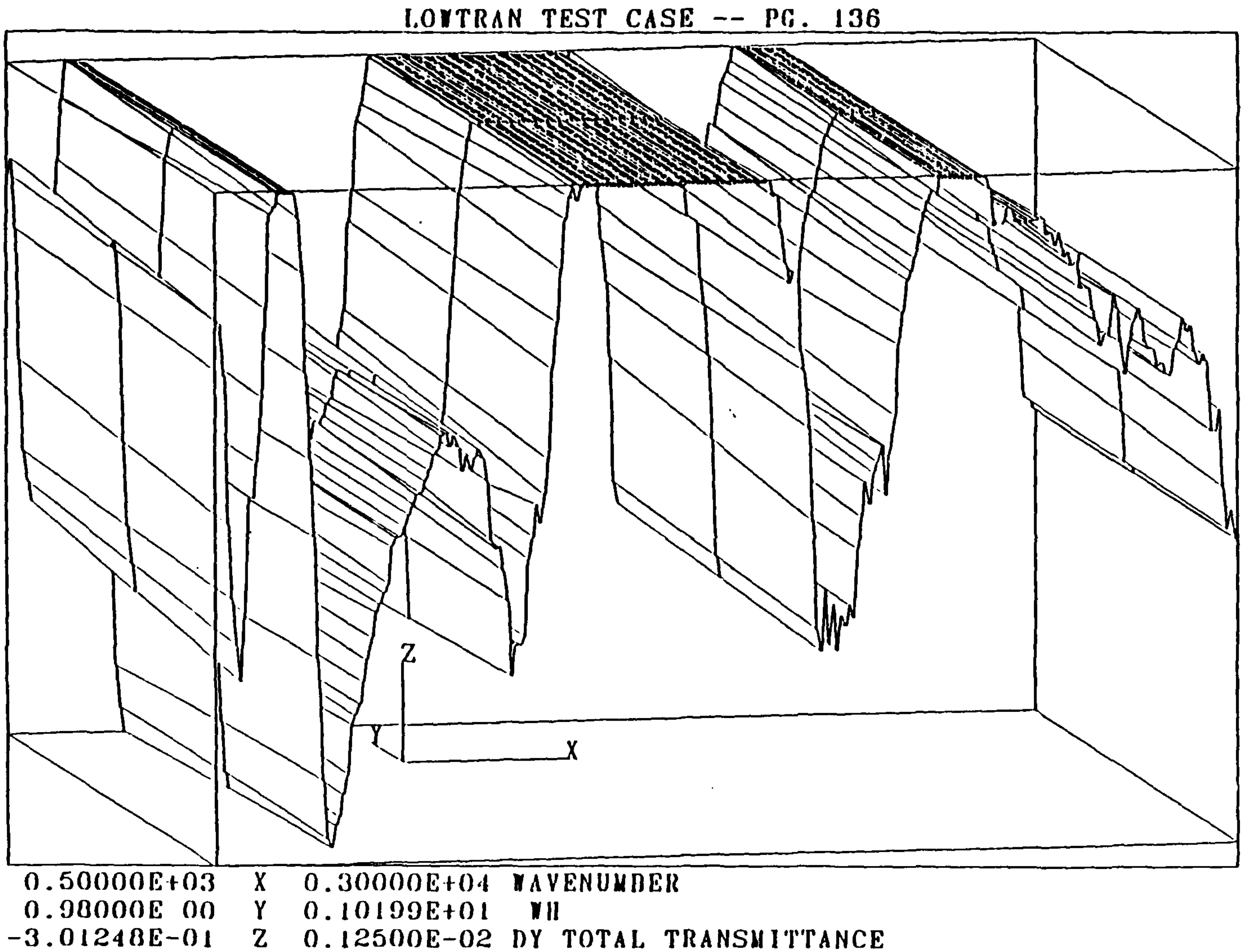


Figure 3-a. 2D diagram of transmittance for 2 km path at sea level for CASE 3. *Two axes are as marked in the figure.*



<u>Figure 3-b</u>. Partial derivative of transmittance in Figure 3-a with respect to the water vapor density for CASE 3. Alternate CARD 3 was used. The first curve in the foreground represents the default water vapor density of 5.9 g/m^3. Three axes are as marked in the figure. The viewing angles are 22.5° and 22.5°.

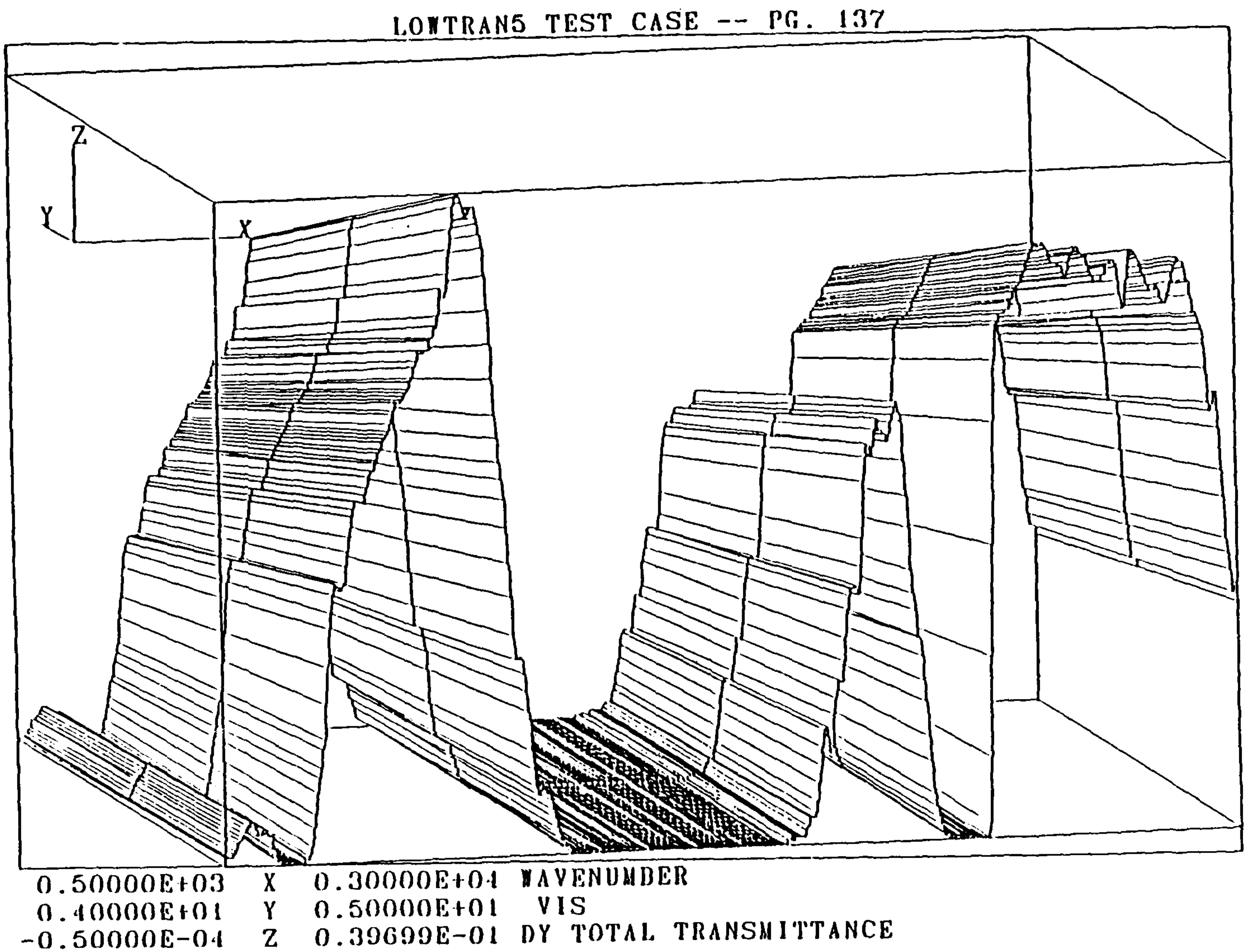


Figure 3-c. Partial derivative of transmittance in Figure 3-a with respect to the visibility for CASE 3. Alternate CARD 3 was used. The first curve in the foreground represents the default visibility of 4 km. Three axes are as marked in the figure. The viewing angles are -11.25° and 11.25°.

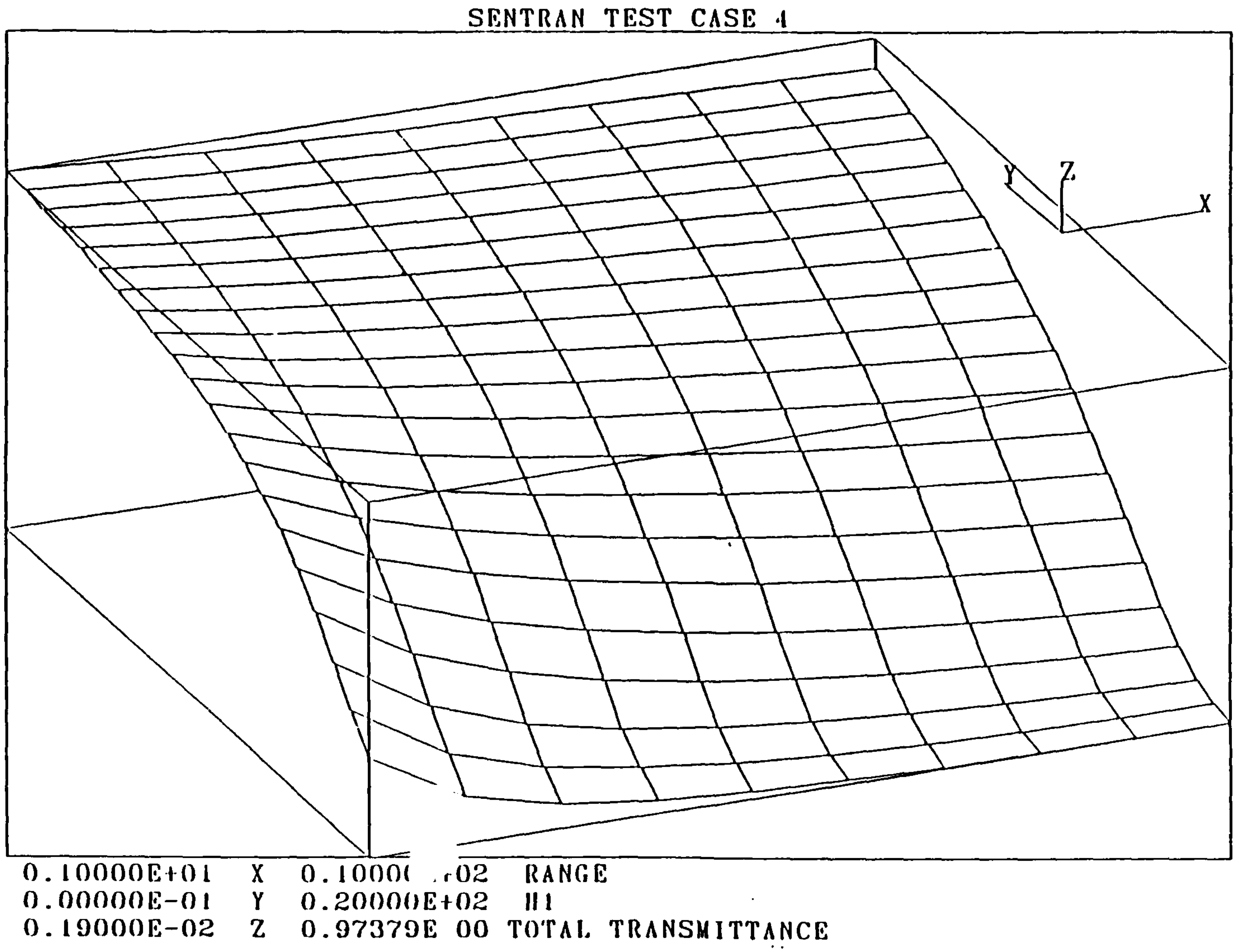


Figure 4. Transmittance at 1300 cm^{-1} for various horizontal paths for CASE 4. Three axes are as marked in the figure. The viewing angles are 22.5° and 45°.

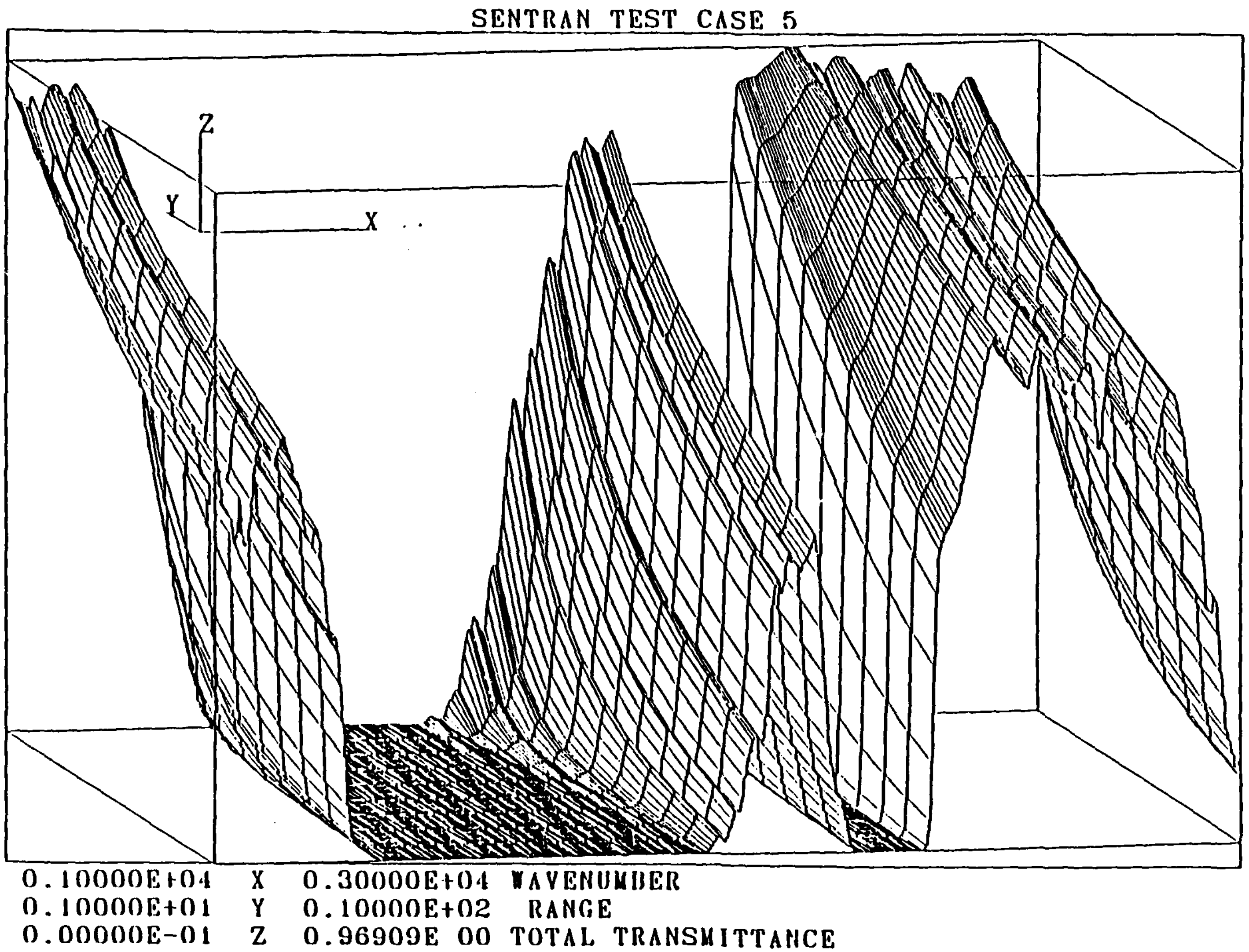


Figure 5. Transmittance at 1 km altitude for various optical range for CASE 5. Three axes are as marked in the figure. The viewing angles are 11.25° and 11.25°.

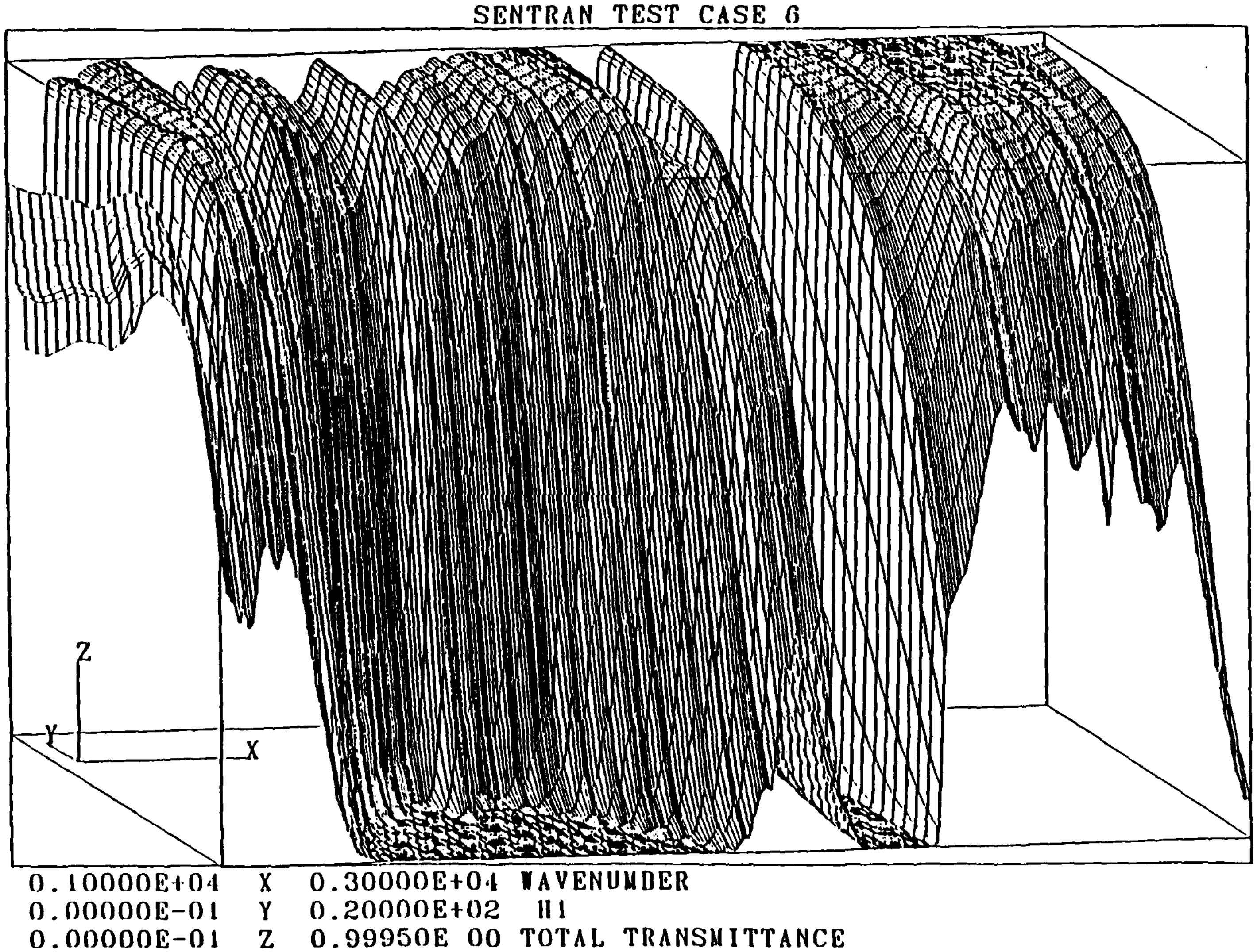


Figure 6. Transmittance for 10 km optical range at various altitudes for CASE 6. Three axes are as marked in the figure. The viewing angles are 11.25° and 11.25°.

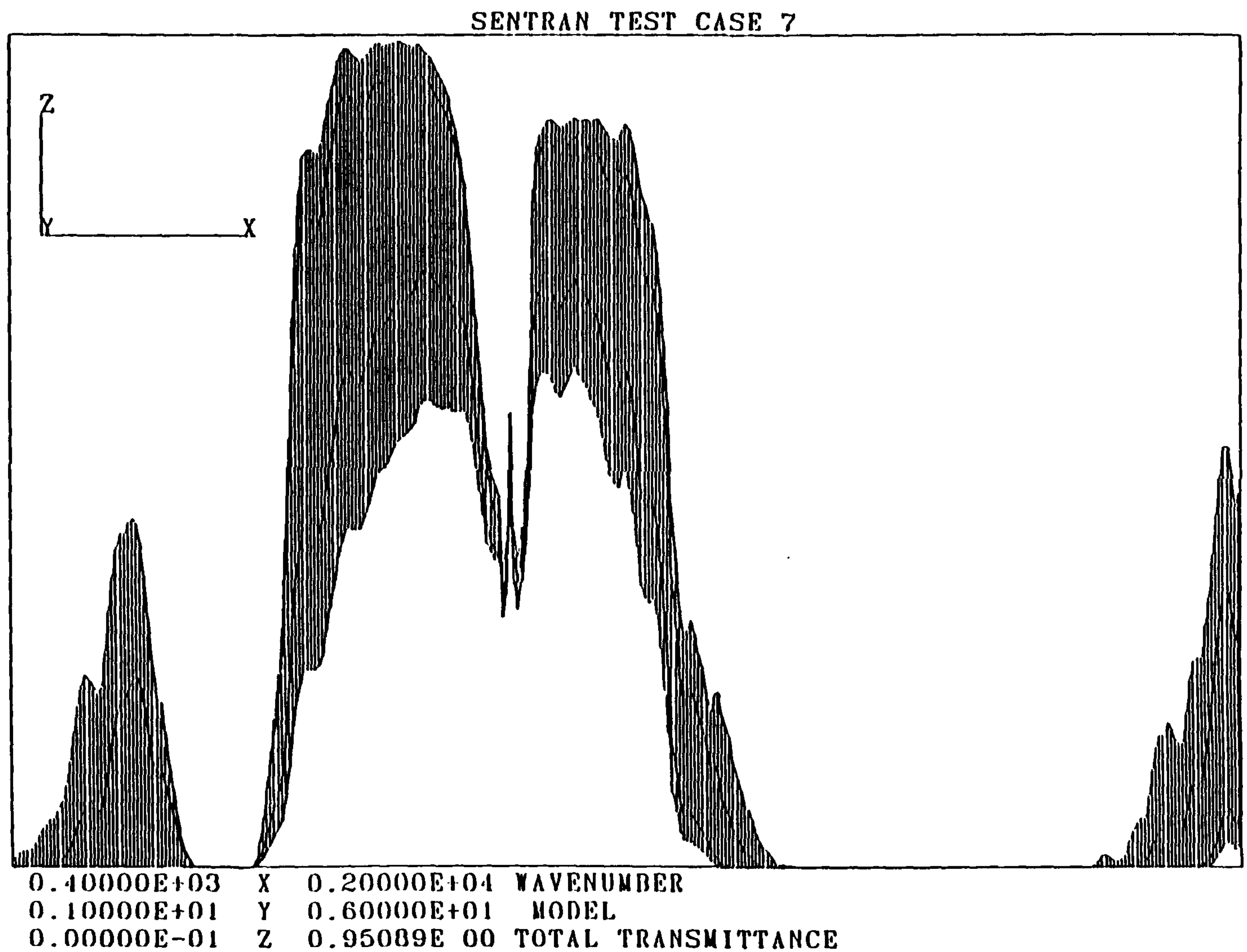


Figure 7-a. Transmittance for optical path from ground to space for six LOWTRAN atmospheric models in CASE 7. Three axes are as marked in the figure. The viewing angles 0° and 0° are used to produce 2D plot with multiple curves.

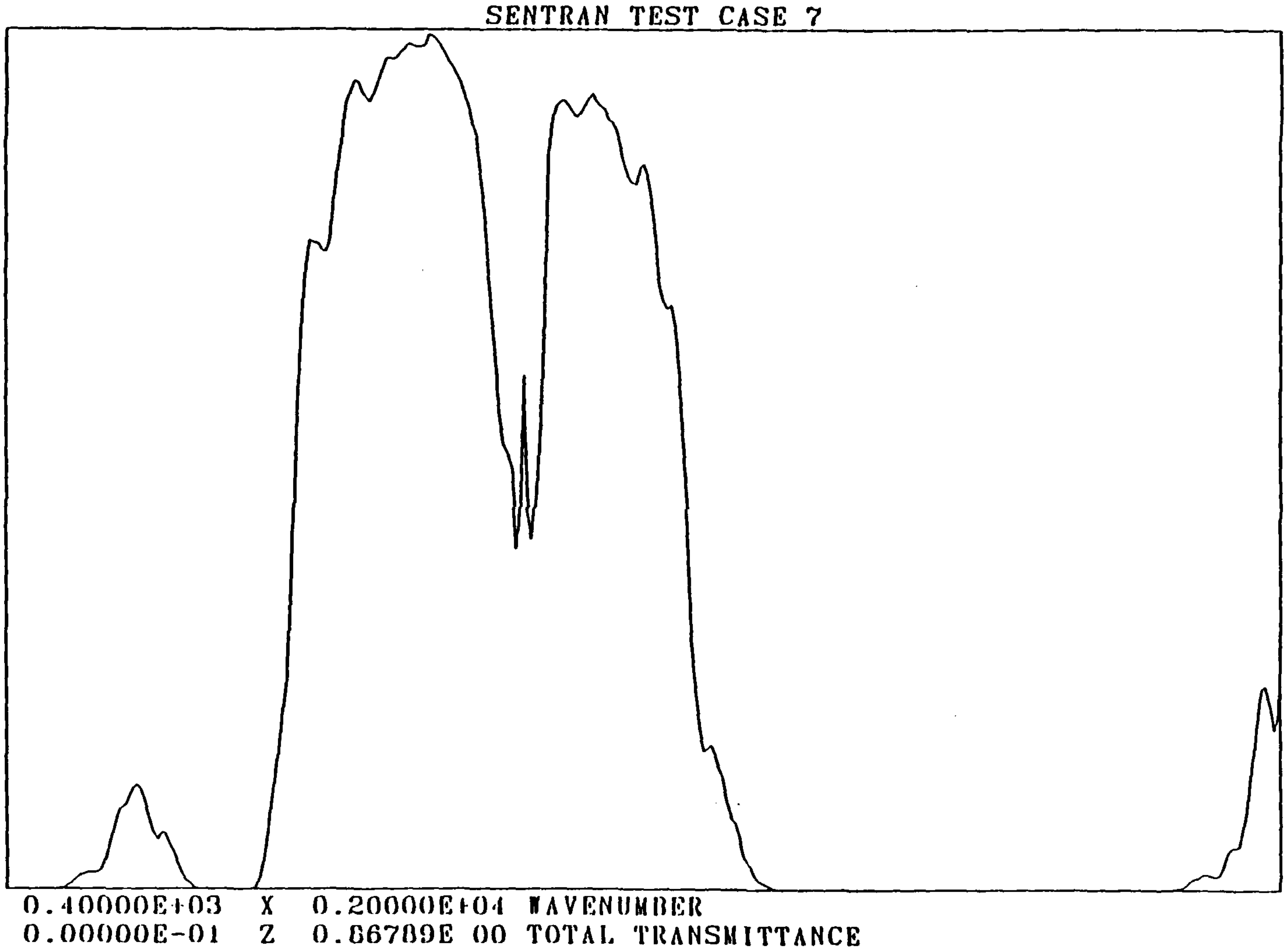


Figure 7-b. Transmittance for optical path from ground to space for the U.S. Standard atmosphere in CASE 7. A single 2D plot is produced. Two axes are as marked in the figure.

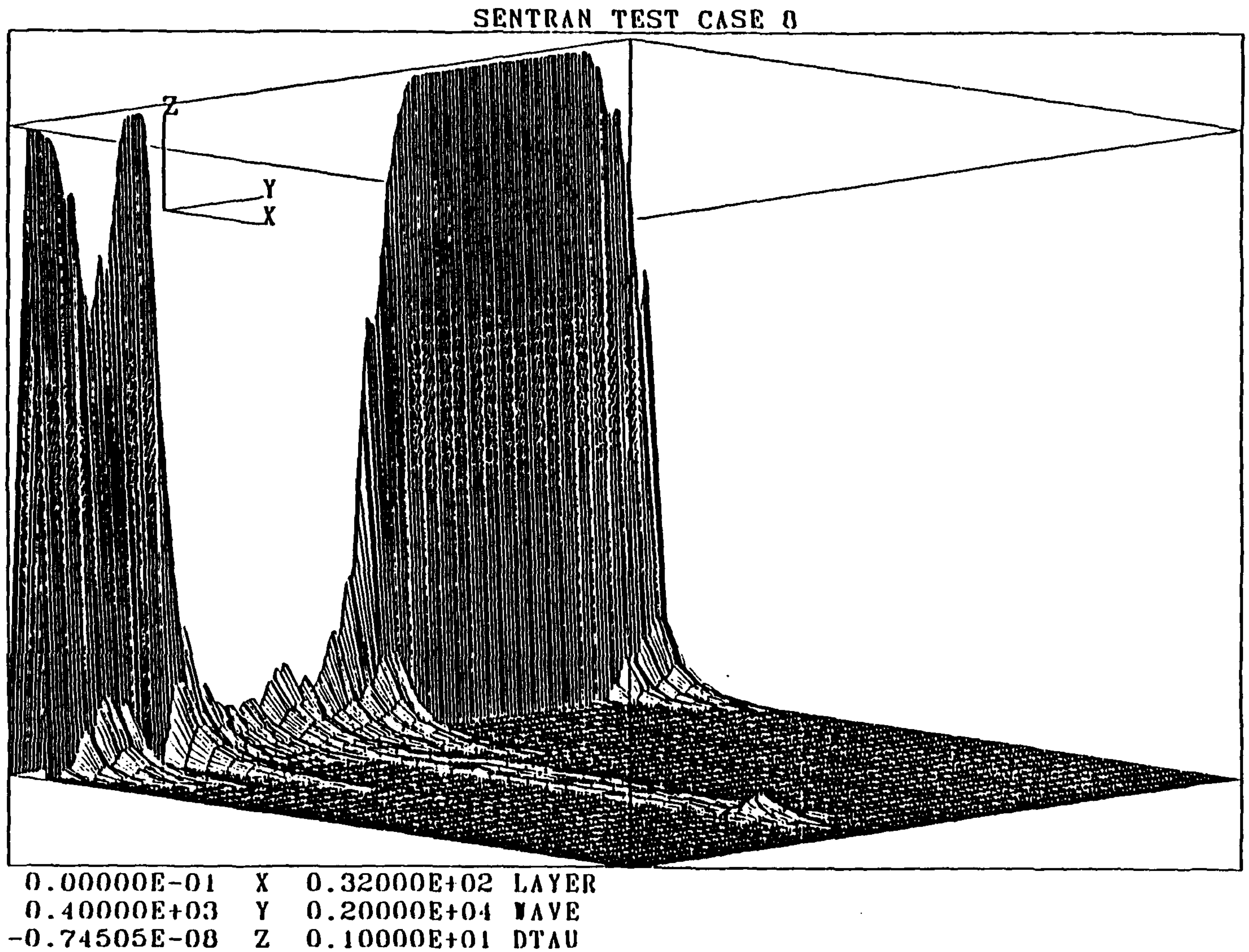


Figure 8. DTAU for optical path from ground to space for the U.S. Standard atmosphere in CASE 8. The viewing angles are -45° and 11.25°. Note that x-axis increases into the foreground.

3. Conclusions

3.1 Conclusions

A sensitivity analysis plan for LOWTRAN was developed in the form of a versatile software, named SENTRAN. SENTRAN provides the user with (1) interactive entry of LOWTRAN input parameter values, including perturbations to climatological variables, (2) intelligent generation of corresponding LOWTRAN input deck images, (3) autonomous post-processing of LOWTRAN outputs for data extraction, (4) partial derivative evaluation, (5) 2D and 3D plot generation, and (6) a help utility. Since SENTRAN furnishes an extremely efficient and user-friendly analysis environment for LOWTRAN users, its usefulness is not limited to sensitivity analysis as was originally intended. It was shown that massive data generation from LOWTRAN can be performed effortlessly in a fraction of the time required without SENTRAN. SENTRAN revolutionized the manner in which we perform LOWTRAN analysis.

3.2 Suggestions for Future Studies

SENTRAN utilizes an external data base of LOWTRAN atmospheric models in order to perturb parameters, such as pressure and temperature profiles, in those models. This was necessitated by the constraint of minimizing modifications to LOWTRAN. It was also necessary to have SENTRAN simulate LOWTRAN input logic for its interactive and intelligent input capability. Naturally, there exists substantial redundancy between SENTRAN and LOWTRAN. A possible improvement upon this situation may be to replace the input section of LOWTRAN by a code similar to EDITOR of SENTRAN, in other words, to consolidate the two codes. The task requires major re-designing of the I/O process, but is certainly a worthwhile undertaking. It makes LOWTRAN much more versatile and efficient; keeping LOWTRAN in step with the current trend of making computer software interactive and user friendly.

Incidentally, it is recommended to alter the data structure of LOWTRAN from a collection of internal BLOCK DATA declarations to that of external data files. This will not only free substantial amount of CPU memory, but will also make data structure much more flexible. This change will also make LOWTRAN appropriate for smaller work-stations which are gaining considerable popularity.

Now that the effectiveness of SENTRAN for LOWTRAN-6 is fully recognized, it is natural to ask for similar software for other meritorious but non-interactive programs such as FASCODE. A SENTRAN derivative designed for FASCODE will have same impact as SENTRAN has for LOWTRAN. Since a new version of LOWTRAN, (LOWTRAN-7) is about to be released, it is also an immediate task to update SENTRAN in order to make it compatible with LOWTRAN-7.

REFERENCES

AT&T 1986. AT&T 3B2/3B15 Computer UNIX System V: FORTRAN-77 XLA+. (Especially, Appendix C-1 for bit manipulation.)

Brayton, R.K., and R. Spence 1980. Sensitivity and Optimization, Elsevier, Amsterdam, The Netherlands.

Burden, R.L., J.D. Faires, and A.C. Raynolds 1981. Numerical Analysis, 2nd Ed., Prindle, Weber, and Schmidt, Boston, MA.

Digital Equipments Corporation 1984. VT240 Series - Programmer Reference Manual. (Especially, Chapter 10 for 4010/4014 Mode.)

Hu, Shin-In 1981. "Sensitivity of Hiking Trail Linear Flow Models to Errors in Input Information," M.S. Thesis, Pennsylvania State University.

Kneizys, F.X., E.P. Shettle, W.O.Gallery, J.H. Chetwynd, Jr., L.W. Abreu, J.E.A. Selby, R.W. Fenn, and R.A. McClatchey 1980. "Atmospheric Transmittance/Radiance: Computer Code LOWTRAN-5," Report AFGL-TR-80-0067, Air Force Geophysics Laboratory, Hanscom Air Force Base, Mass.

Kneizys, F.X., E.P. Shettle, W.O.Gallery, J.H. Chetwynd, Jr., L.W. Abreu, J.E.A. Selby, S.A. Clough, and R.W. Fenn 1983. "Atmospheric Transmittance/Radiance: Computer Code LOWTRAN-6," Report AFGL-TR-83-0187, Air Force Geophysics Laboratory, Hanscom Air Force Base, Mass.

Lakshmanan, R. 1977. "Sensitivity Analysis in Chemical Systems Via Geometric Programming," M.Eng. Thesis, Pennsylvania State University.

Radonovic, L. (ed.) 1966. Sensitivity Methods in Control Theory, Pergamon Press, Oxford, England.

Tomiyama, K. 1986. "Atmospheric Modeling for Operational Tactical Decision Aid," Final Report, Contract Number F49620-85-C-0013, Air Force Office of Scientific Research.

ACKNOWLEDGEMENTS

The authors would like to thank Gail Anderson, Frank X. Kneizys and Jim Chetwynd, all of the Optical Physics Infrared Group, the Air Force Geophysics Laboratory (AFGL), for continuous support in pursuing this research. We would also like to acknowledge valuable help on aerosol extinction from Eric Shettle, also at AFGL. We cannot forget mentioning Dennis W. Richardson who helped us go through testing various SENTRAN versions.

Appendix A. LOWTRAN Modifications

There is a small amount of modifications to LOWTRAN that is necessary to extract layer-wise absorption contributions. This information is contained in a variable DTAU which appears in an intermediate step of radiance computation. Therefore, a PRINT and other associated statements need to be added to LOWTRAN in order to extract this information. Also added are the codes dealing with naming conventions for input and output files. A list of those added lines is given in this appendix. More details of the modification to LOWTRAN will be discussed in the SENTRAN Programmers Guide for those users who need to customize SENTRAN to their environment. The Guide will be available as a separate document.

A-1. Modifications to the Main Program

The following lines replace lines LWT 2815 through LWT 2840 as shown.

```
      C*****TAPE7 RESPECTIVELY                                          LWT 2810
      C=========================================================C
      C     CHANGES FOR FILE COMPATIBILITY W/ SENTRAN           C
      C=========================================================C
            DEKNAM=' '
            OPEN(UNIT=50,FILE='FLAG.TRN',STATUS='OLD',ERR=10)
            READ(50,*,END=10)I
            READ(50,'(A20)',END=10)DEKNAM
      10    CLOSE(50)
      C                           --- SET DEFAULT INPUT
      C                               & OUTPUT NAMES
            IF (DEKNAM .EQ. ' ') THEN
               OUTFIL='TAPE7.OUT'
               DEKNAM='INPUT'
            ELSE
               I=INDEX(DEKNAM,'.')
               IF (I .NE. 0) THEN
                   OUTFIL=DEKNAM
                   OUTFIL(I:I+3)='.OUT'
               END IF
            END IF
             IRD = 20
             IPR = 6
             IPU = 7
              OPEN (IRD,FILE=DEKNAM,STATUS='OLD')
              OPEN (IPR,FILE='OUTPUT.DAT',STATUS='NEW')
              OPEN (IPU,FILE=OUTFIL,STATUS='NEW')
      C======================================C
      C     END OF FILE MODIFICATIONS        C
      C======================================C
             PI=2.0*ASIN(1.0)                                           LWT 2845
```

A-2. Modifications to Subroutine TRANS

The following lines are inserted between line TRA 310 and TRA 315 as shown.

```
      DATA   CF1/3.159E-28/,CF2/2.75E-04/                              TRA  310
C==============================================C
C ----- CODE HERE TO EXTRACT DTAU VALUES        C
C==============================================C
      ITRFLG=0
      OPEN(UNIT=50,NAME='FLAG.TRN',ERR=1000,STATUS='UNKNOWN',READONLY)
      REWIND 50
      READ(50,*,END=1000)ITRFLG
1000  CLOSE(UNIT=50)
      IF (ITRFLG .EQ. 1) THEN
         OPEN(UNIT=50,NAME='DTAU.DAT',ERR=1010,STATUS='UNKNOWN')
         WRITE (50,*)V1   ,V2    ,DV
        WRITE (50,*)IKLO,IKMAX,1
       END IF
1010  CONTINUE
C======================================================C
C     END OF PART 1 OF CODE TO EXTRACT DTAU VALUES     C
C======================================================C
      RADMIN=1.0E+30                                                   TRA  315
```

The following lines are inserted between line TRA 1165 and TRA 1170 as shown.

```
      DTAU=TLOLD-TLNEW                                                 TRA 1165
C=====================================================C
C     DTAU VALUES ARE WRITTEN TO FILE                 C
C              DTAU.DAT                               C
C=====================================================C
      IF (ITRFLG .EQ. 1)  WRITE(50,*) IK,IV,DTAU
C=====================================================C
      IF (DTAU.LT.1.0E-5.AND.TLNEW.LT.1.0E-5) GO TO 220                TRA 1170
```

Appendix B. SENTRAN Users Guide & Tutorial

This appendix is written in such a way that it can be reproduced and used as a self-contained Users Manual. All the necessary information for a novice user to start using SENTRAN are provided in this manual as tutorials.

SENTRAN Users Guide & Tutorial

Prepared for

The Air Force Office of Scientific Research
Bolling Air Force Base
Washington, D.C.

Under Contract Number

F49620-87-C-0057

Prepared by

Ken Tomiyama, and Michael Hogan
The Department of Electrical Engineering
Pennsylvania State University
University Park, PA 16802
(814) 865-7667

August, 1988

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

I. INTRODUCTION[1]

SENTRAN is a general purpose code which facilitates the analysis of responses of LOWTRAN (Kneizys et al. 1980, Kneizys et al. 1983) to the perturbation of its input parameters. SENTRAN is primarily designed as a comfortable, interactive interface to LOWTRAN-6 with special provisions for perturbation analysis. However, SENTRAN is not limited to interactive usage and contains special features which permit it to be used in batch environments. Using SENTRAN, one can easily extract, analyze, reduce and plot LOWTRAN data, performing analysis problems that would be difficult or impossible through brute-force techniques.

We are fully aware that learning to use a complicated program is a time consuming and somewhat painful process. In light of this fact, we have made every effort to make the act of learning SENTRAN as easy as possible. SENTRAN's documentation is organized in three volumes, each targeted at users with different levels of experience in using SENTRAN and/or computers in general. This document is targeted at novice SENTRAN users, and provides them with an overview of SENTRAN's structure and usage, concluding with selected case studies. Details of command usage, in a quick reference format, may be found in the "SENTRAN TECHNICAL REFERENCE", while details of program structure and tips for customizing your system (via modifying the source code) may be found in the "SENTRAN PROGRAMMER'S GUIDE".

Familiarity with LOWTRAN is presumed. Therefore, the "Atmospheric Transmittance/Radiance: Computer Code LOWTRAN 6" manual should be used as a companion guide for learning the SENTRAN/LOWTRAN system.

---

1 This manual was prepared as an appendix to the final report, Sensitivity Evaluation Plan for LOWTRAN.

II. STRUCTURAL OVERVIEW

II-1. Design Criteria

SENTRAN's design is based on the following general criteria:

- must provide a tool for sensitivity analysis
- must be highly portable and inexpensive
- must be user friendly
- must minimize turnaround time for analyses
- must make extensive use of graphics for data presentation
- must provide data analysis and reduction tools

Other, more specific elements of the design specifications include the following:

- standard LOWTRAN models may be perturbed
- layer by layer change in transmittance as calculated by LOWTRAN (DTAU) may be extracted
- active absorbers on the spectral interval under study be displayed

The following paragraphs describe how SENTRAN addresses these design issues.

SENTRAN was originally conceived as a tool with which to analyze LOWTRAN's sensitivity to variations in climatological input data. To this end, SENTRAN enables you to easily perturb climatological input parameters via a special purpose data generation language. Further, the user can compute partial derivatives of LOWTRAN generated data with respect to these parameters. This process is highly automated, requiring little effort on the part of the user as SENTRAN is "intelligent" enough to keep track of the details of parameter variation. Furthermore, SENTRAN utilizes special numerical techniques to insure second derivative continuity at each point of the LOWTRAN data mesh and calculate derivatives quickly. Using these capabilities, users can rapidly determine those regions where LOWTRAN's calculations are most sensitive.

SENTRAN is designed to be inexpensive and highly portable, while maintaining a reasonably high level of performance. These goals dictate the use of highly portable code and common, inexpensive standards for graphics and terminal control. To this end, SENTRAN is coded in FORTRAN-77[2] and utilizes the TEKTRONICS

---

[2] SENTRAN is compatible with a common extended version of FORTRAN, "the Department of Defense Supplement to ANSI X3.9-1978 for binary pattern processing" (for example, AT&T 1986). Your compiler must support these extensions for SENTRAN to work properly.

4010/4014 standard for graphics and the American National Standards Institute (ANSI) standard for terminal control (for example, Digital Equipment Corporation 1984). Furthermore, SENTRAN's graphics and terminal control kernels 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 and is an ideal terminal for interactive viewing of SENTRAN graphics.

User friendliness is one of the single greatest considerations in SENTRAN's design. SENTRAN is projected to have 8000+ lines in its first release, most of which are devoted to providing you with a comfortable working environment, without compromising flexibility or power. User friendliness is implemented in a number of ways. Some of the more general of these are as follows:

- SENTRAN is virtually crash proof, using character oriented input for command strings and numerical values. These are then parsed for "sanity" before they are executed.
- SENTRAN is case insensitive, responding to commands in upper, lower or mixed case.
- SENTRAN always provides you with abundant feedback, providing step by step prompts and ample information on the current state of the system.
- SENTRAN can parse complicated input strings, bypassing input prompts. This permits veteran users to use SENTRAN with increased speed.
- SENTRAN provides sensible defaults wherever possible, reducing the chance of erroneous input.
- SENTRAN provides on-line help, minimizing the amount of time required to learn the program.

While this list is by no means complete, it provides an idea of the user friendly features of SENTRAN. Collectively, these features free you from the need to concentrate on file and data manipulation, allowing you to focus on the scientific aspects of your LOWTRAN analysis problems.

SENTRAN makes extensive use of graphics to represent data. 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 SENTRAN via 3D surface plots, enabling you to visualize LOWTRAN's response to the simultaneous variation of two parameters. These plots can be archived as .TEK files, facilitating hard-copy generation and/or later perusal on a graphics terminal.

Data analysis and reduction tools are provided along with graphics in an interactive module (GRAPH & ANALYZE). The analysis tools include common data manipulations:

- flexible, component-wise extraction of LOWTRAN data
- logarithmic transformation of data (LOG)
- partial derivatives of order 1 and 2 with respect to independent axes (DX, DY, DDX, DDY, DYDX, DXDY)
- axis swapping (SWAP)
- transmittance to optical depth conversion (T2A)
- optical depth to transmittance conversion (A2T)
- input of reduced data (SENTRAN can read raw X,Y,Z files)
- output of reduced data as a raw X,Y,Z data file (WRITE)
- output of a cosmetic data file which describes the data set and all transformations to which it was subjected (COSMETIC)

Subsequent graphing of the data set will reflect any transformations to which it was subjected. Furthermore, the capability of saving the reduced data set as raw X, Y, Z data while deleting the original LOWTRAN TAPE7 output file affords a substantial savings in data storage.

II-2. Program Structure

SENTRAN is divided into five main modules, each of which is subdivided according to the following table:

Table 1. List of SENTRAN modules.

LOAD/SAVE	LOAD
	SAVE
EDIT	CARD 1
	CARD 2
	CARD 2a
	CARD 2b
	CARD 2c
	CARD 2d
	CARD 3
	ALT-CARD 3
	CARD 3a
	CARD 3b
	CARD 4
COMPILER	DECK COMPILER
	DEBUG
	MAJOR ABSORBERS
GRAPH & ANALYZE	DATA EXTRACTION
	INTERACTIVE ANALYSIS/GRAPHING
	GRAPH & ANALYZE HELP
	REDUCED DATA I/O
HELP	
LOG	
NOPROMPT	
ZAP	

The following sections outline these modules in some detail.

II-2-1. LOAD/SAVE

Images of LOWTRAN input parameters and directives for their perturbation are contained in files known as METHODOLOGY files. These files enable you to store various methodologies and use them as starting points in any given experiment. The SAVE/LOAD module provides a means for methodology I/O, loading and saving selected files to and from SENTRAN's editing buffer. Once a methodology file has been loaded into SENTRAN's editing buffer, you may use the EDITOR to modify its contents (see Section II-2-2).

It is worth noting that ".MTH" extensions are presumed on methodology files unless you specify a different extension. For example, typing "LOAD EXAMPLE" will load a file named EXAMPLE.MTH into the editing buffer, while typing "LOAD WIERD.EXT" will load a file named WIERD.EXT.

Another point worth noting is that the most recent method generated is always copied into a special file named LAST.MTH. This file is loaded into SENTRAN immediately upon execution, provided that it exists, and provides a sensible default methodology. Therefore, you are cautioned against saving methodology files named LAST.MTH or tampering with the LAST.MTH file in any way.

II-2-2. EDIT

The EDIT module of SENTRAN provides a flexible means of modifying LOWTRAN input decks. The editor permits the entry of climatological data and directives for data perturbation, provides flexible movement within a card image and among card images, and emulates LOWTRAN's logical flow through input decks, eliminating the need to edit unnecessary input parameters. Since the EDITOR is a complex module, the next several paragraphs are devoted to its description. The following diagram should serve as a useful visual aid for these descriptions.

Each screen's physical layout conforms to the following standard (see Fig. 1). The name of the current card image appears at the top of the editing screen, while the name of the LOWTRAN input variables appear along the left hand column. Values for each of the LOWTRAN inputs appear to the immediate right of the list of names, along with symbolic directives for their variation. Variables which affect the logical flow through LOWTRAN decks are marked with a "*", and are subject to certain restrictions. 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 the figure below, MODEL is the line currently being edited. After the input line is entered, SENTRAN converts the string to upper case and redraws the line in a special format, insuring an organized appearance for the editing screens. Using the data entry format, along with special commands for cursor movement (described in a following paragraph), you can quickly generate LOWTRAN deck images with little effort.

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 SENTRAN passes to LOWTRAN upon execution. The PERTURBATION DIRECTIVE is a statement which is interpreted by SENTRAN's compiler module in order to effect a perturbation of the associated parameter. This is shown in the following diagram.

```
            EDITING CARD 1

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

    MODEL *    ▒5    3 6 4 2 1 <---------------- Perturbation
    ITYPE *     3                                 Directives
    IEMSCT*     0
    M1 ...      0 <----------------------------- Nominal Value
    M2 ...      0
    M3 ...      0
    IM ...      0
    NOPRT*      0

 FOLLOWING PARAMS. USE A PERTURBATION VALUE

    TBOUND      0.000000
    SALB        0.000000
```

Figure 1. Editing screen for CARD 1.
(▒ indicates cursor position.)

There are several input strings which are reserved for cursor control. These commands are:

Table 2. List of cursor control commands in EDITOR.

UP n	- move the cursor up n lines
DN n	- move the cursor down n lines
PU	- move up one page (card image)
PD	- move down one page (card image)
END	- terminate editing session, proceed to main menu
mm *	- change the nominal value to mm, but keep old perturbation directive

Note that the "n" values are optional, and their absence implies n=1. Cursor control commands do not affect data on the currently active input line.

As editing is taking place, you will notice that some LOWTRAN input decks and some variables within a deck will not be made available for editing. This is due to the fact that SENTRAN's editor emulates LOWTRAN's flow through input decks. This aids you in two ways: 1) it eliminates unnecessary input and, 2) it serves as a form of debugging tool, in that the absence of an expected card image implies an erroneous value in a previous card.

The final element of the editing session is the opportunity to select the extraction of layer-wise change in transmittance data from LOWTRAN (DTAU). A reply of "YES" to the prompt "EXTRACT DTAU DATA ?" will set a flag in a special file which can be read by suitably modified versions of LOWTRAN. This will cause LOWTRAN to write layer-wise change in transmittance data to a file named "DTAU.DAT". Users are cautioned that LOWTRAN does not activate the DTAU calculation unless IEMSCT is set at 1 or 2 (radiance or Solar/Lunar radiance) on CARD 1.

II-2-3. COMPILE

While the entry of LOWTRAN data and symbolic directives for LOWTRAN input data variation are handled by the EDITOR, the actual task of generating LOWTRAN input decks is handled by the COMPILER. The compiler performs four distinct functions:

1) It generates LOWTRAN input decks by interpreting edited input according to a special data generation syntax.
2) It provides a list of active absorbers within the spectral interval of interest.
3) It automatically generates a METHODOLOGY file with the same first name as the input deck generated (example: the command "COMPILE EXAMPLE" will produce two files, EXAMPLE.INP and EXAMPLE.MTH, as a LOWTRAN input deck and methodology file, respectively).
4) It optionally generates a special debug file named SEN.ERR.

The following paragraphs detail the inner workings of the data generation language and the compiler's function.

SENTRAN permits symbolic manipulation of LOWTRAN variables through a simple interpreted language known as DATA GENERATION LANGUAGE. Four basic syntaxes are supported, each possessing a different physical interpretation, allowing you to select the syntax which best fits your needs. The syntaxes supported are listed in Table 3 below.

Table 3. List of perturbation directive syntaxes.

SYNTAX NAME	SYNTAX FORMAT
% SYNTAX	NOMINAL_VALUE % PERTURBATION
+/- SYNTAX	NOMINAL_VALUE +/- PERTURBATION
ITERATION SYNTAX	NOMINAL_VALUE [START] TO FINAL [STEP_SIZE]
LIST SYNTAX	NOMINAL_VALUE LIST_OF_VALUES

In this table, NOMINAL_VALUE, PERTURBATION, START, FINAL and STEP_SIZE are all single numerical values. LIST_OF_VALUES is a list of one or more values. Terms appearing in square brackets "[]" are optional. The "%", "+/-" and "TO" terms are actual elements within the string. Type them exactly as they appear. Consider the following editing screen, which contains examples of most of the valid perturbation syntaxes.

```
            EDITING CARD 3

FOLLOWING PARAMS USE A PERTURBATION VALUE    SEQUENCE PRODUCED

    H1 ...      5.000     %20                4.0, 5.0, 6.0
    H2 ...     10.000     %10                9.0, 10.0,11.0
    ANGLE      45.000     TO 48              45.,46.,47.,48.
    RANGE      10.000     TO 20 STEP 5       10.0, 15.0, 20.0
    BETA        5.000     0 TO 10 STEP 5     0.0, 5.0, 10.0
    RO       6370.000     6371 6372          6370.,6371.,6372.

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

    LEN*        0
```

Figure 2. An editing screen with several valid perturbation syntaxes and the sequences which they produce. Note that this card would probably produce invalid results if used with LOWTRAN. It is presented only for demonstration purposes.

SENTRAN places little restriction on the number of parameters which may be perturbed, or the range over which they may vary. 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 LOWTRAN's parameter space, with the unfortunate side effect of generating enormous quantities of data. For example simultaneous perturbation of 10 parameters over all 100 values possible would result in a

TAPE7.OUT file containing 1E20 different runs! In fact, SENTRAN's generative capabilities far outweigh its analysis capabilities, since SENTRAN can only analyze in terms of two simultaneous perturbations.

SENTRAN's compiler supports two options which control the compiler's movement through parameter space. These are the MESH and NOMESH options. 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. In light of this fact, the usefulness of perturbation directives such as "5.000 0 TO 10 STEP 5" is clear; in a NOMESH compilation, the parameter associated with this perturbation directive is held at the value 5 as other parameters are perturbed.

Another fact worth noting is that the compiler "remembers" the last compilation mode selected and utilizes this as the default mode for subsequent compilation. Naturally, 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 that one parameter is perturbed, and is the appropriate choice when little or no synergistic effect is expected. If only one parameter is perturbed, or no parameters are perturbed, the MESH and NOMESH options are equivalent.

Another option supported by SENTRAN's compiler is the ability to write compiler error messages and information on major absorbers within the current spectral interval to a special file. This is the ERROR option in the compiler. 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. Thus, the ERROR option serves as a crude analysis tool, as well as a potentially useful debugging aid.

While the preceding paragraphs cover the compiler's mechanics in some detail, the manner in which the compiler is actually invoked has not yet been discussed. Like most of SENTRAN's main functions, the compiler is invoked from the main menu, either by typing "3", or any sub-string of the word "COMPILE". You have the option of imbedding compiler arguments (i.e. the card file name and compiler options) within the initial command string, or of being prompted for them on a step by step basis. The following diagrams detail the compiler command structure via a schematic and several concrete examples.

compile [deck name] [/MESH /NOMESH /ERROR]
3 [deck name] [/MESH /NOMESH /ERROR]

Figure 3. COMPILER syntax schematics. "compile", "3", "/MESH", "/NOMESH" and "/ERROR" are literal strings, to be typed exactly as they appear here. "deck name" is a string corresponding to the desired LOWTRAN input deck name ("SAMPLE.INP" for example). Terms enclosed in square brackets are optional. The square brackets should not be typed.

?compile test /m/e	compiles deck named "test.inp" as mesh and generates an error file
?3 **LOWTRAN INPUT CARD NAME AND OPTIONS ?** test /n	compiles deck named "test.inp" as nomesh, no error file generated
?com test.wow	compiles deck named "test.wow" using last mode (MESH or NOMESH) as default, no error file generated
?c test.dumb /m /n /e	compiles deck named "test.dumb" as NOMESH, demonstrating that MESH and NOMESH are exclusive, with NOMESH taking precedence

Figure 4. COMPILER syntax examples. The left-most column is SENTRAN's prompt (bold text) and your response (normal text). The right-most column is a description of SENTRAN's interpretation of the input line(s).

II-2-4. GRAPH & ANALYZE

The GRAPH & ANALYZE (G&A) module of SENTRAN is by far the most complex element of the program, providing the following:

1) Flexible options for the extraction of data from LOWTRAN's TAPE7.OUT file, raw X-Y-Z files or the DTAU file
2) Tools for data manipulation, analysis and archiving
3) Commands for generating graphical plots of data and special graphics files for archival and hard-copy

The GRAPH & ANALYZE module has its own on-line help utility as well. The following paragraphs treat the GRAPH & ANALYZE module in detail.

Generally speaking, LOWTRAN is executed between usage of the COMPILER and GRAPHICS & ANALYSIS modules, since G&A extracts its data from LOWTRAN's TAPE7.OUT data file based on the current contents of the EDITING buffer. Since the EDITING buffer contents are based upon LAST.MTH when operation of the program is begun, and since LAST.MTH is refreshed every time that an input deck is COMPILED, the default sequence of COMPILE, RUN LOWTRAN, GRAPH will successfully decode the TAPE7 file without any additional effort on your part. If you depart from the COMPILE, RUN LOWTRAN, GRAPH sequence then you must insure that your EDITING buffer corresponds to the TAPE7 file which you wish to read. This is accomplished by loading the methodology associated with this TAPE7 file. If this is not done, then the data which is extracted from the TAPE7 file may make no physical sense (if it can be read at all!).

Upon entry into the G&A module, you will be prompted for a number of options regarding G&A's sources of data. These selections control how SENTRAN extracts data from various sources, although from your point of view the choices will appear to relate to selection of two independent axes (X and Y) and one dependent axis (Z) for surface plotting. Logical flow through this section of code is fairly complex and is not easily described with words. Suffice it to say that SENTRAN is quasi-intelligent, presenting you with only those data extraction options which make sense in light of the current contents of the EDITING buffer and your answers to preceding data extraction options; the intricacies of data extraction should be almost completely transparent to you. Figure 5 plays a dual role of being a complete list of possible options, and a chart for logical flow among those options. While the logical flow may seem imposing, we stress again that it is transparent to the user and does not complicate usage of the program. See the module by module description and tutorial for more examples.

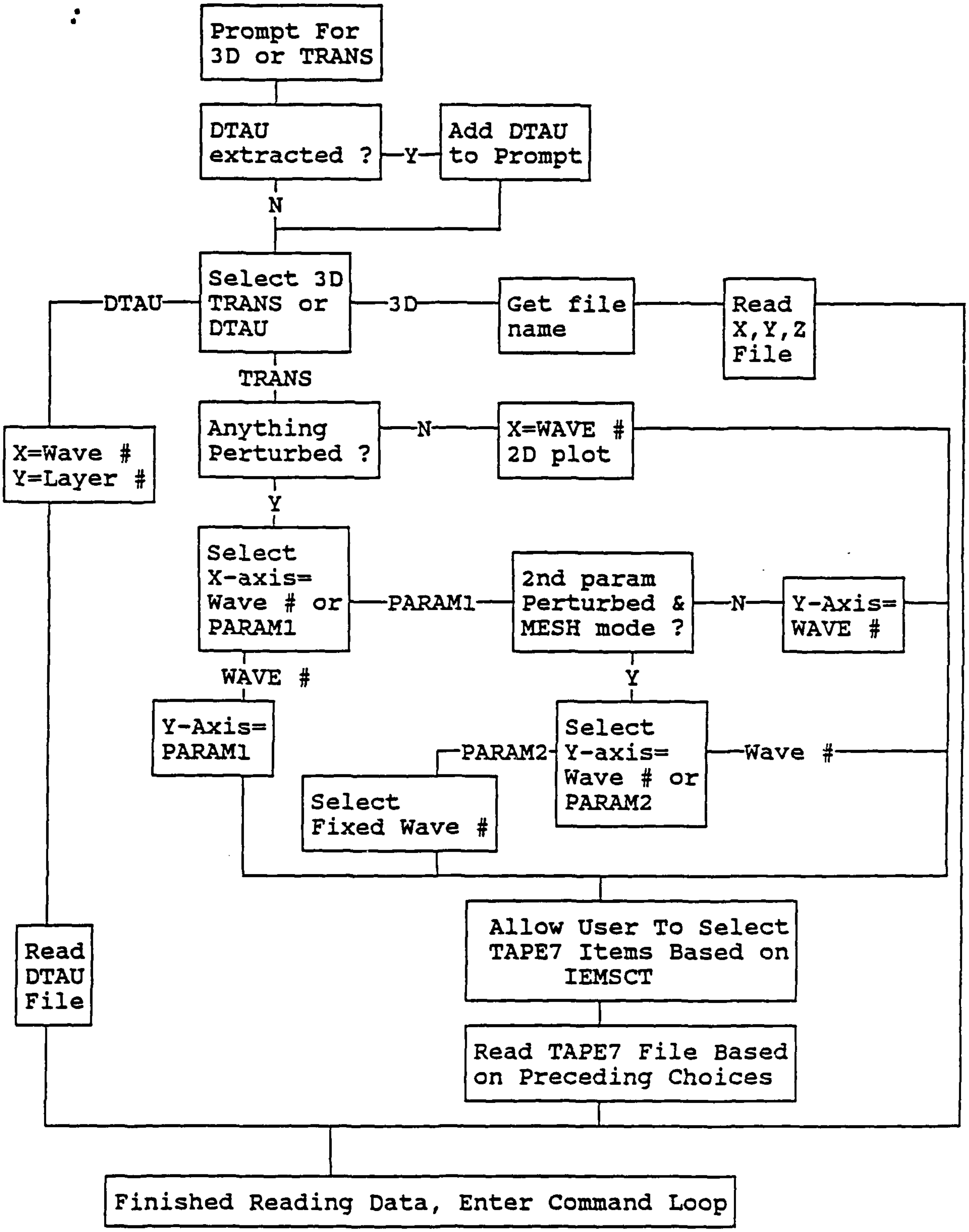


Figure 5. Simplified flow diagram for SENTRAN input data selection

List of data source prompts

G&A data source prompts are discussed below, with descriptions of logic causing execution and the meaning of various choices. Note that those positions filled by PARAM1 and PARAM2 will actually contain the names of the first and second LOWTRAN variable perturbed, respectively.

PROMPT 1	PLOT TYPE: 1)3D-DATA 2)TRANSMITTANCE 3)DTAU
LOGIC	This is always the first prompt
MEANING	Data source may be raw 3D data file in X,Y,Z form OR transmittance, atmospheric radiance etc (SENTRAN will modify 2nd choice's prompt according to IEMSCT's value) OR layer wise change in transmittance (if available, otherwise there is no 3rd choice).

Prompts resulting from selection of TRANSMITTANCE[3]

PROMPT 2	X-AXIS : 1)WAVENUMBER 2)PARAM1
LOGIC	Issued if transmittance selected from PROMPT 1 AND a LOWTRAN variable was perturbed
MEANING	Allows you to select wavenumber or param1 as X-Axis.
PROMPT 3	Y-AXIS : 1)WAVENUMBER 2)PARAM2
LOGIC	Issued if transmittance selected at PROMPT 1 AND param1 selected at PROMPT 7
MEANING	Allows you to select wavenumber or param2 as Y-Axis.
PROMPT 4	WHICH WAVENUMBER ?
LOGIC	Issued if transmittance selected at PROMPT 1 AND param1 selected for X-Axis AND param2 selected for Y-Axis
MEANING	Allows you to select a fixed wavenumber for surface plots, since two independent axes have already been chosen.
PROMPT 5	Z-AXIS : 1)TOTAL 2)H2O 3)CO2 4)OZONE ...
LOGIC	Issued if transmittance selected at PROMPT 1
MEANING	Allows you to select any available column from the TAPE7.OUT file. Thus, various sub-components of total transmittance, radiance or irradiance may be plotted and manipulated. Note that the prompt's text may vary based on whether you are calculating transmittance, radiance irradiance etc.

Once you have responded to the questions regarding data sources, the program enters a special loop, interpreting single

---

[3] Although the term TRANSMITTANCE is used throughout this section, appropriate adjustments in prompts will be made if you are actually calculating radiance, scattered radiance or irradiance.

line commands and immediately executing 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. 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. These commands can be divided into three main groups: 1) numerical commands, 2) plotting commands, and 3) I/O and control commands. The following figures are of a typical G&A command screen and a typical plotting screen, and may serve as a useful guide in the following discourse.

```
       SENTRAN GRAPHICS & ANALYSIS MODULE

PLOT TYPE: TRANSMITTANCE           FILE NAME : SECOND.OUT

X-AXIS    : RANGE

Y-AXIS    : H1

WAVENUM. :  1299

UNITS OF : CM-1

Z-AXIS    : TOTAL TRANSMITTANCE


COMMAND ?
```

Figure 6. A typical GRAPH & ANALYZE screen.

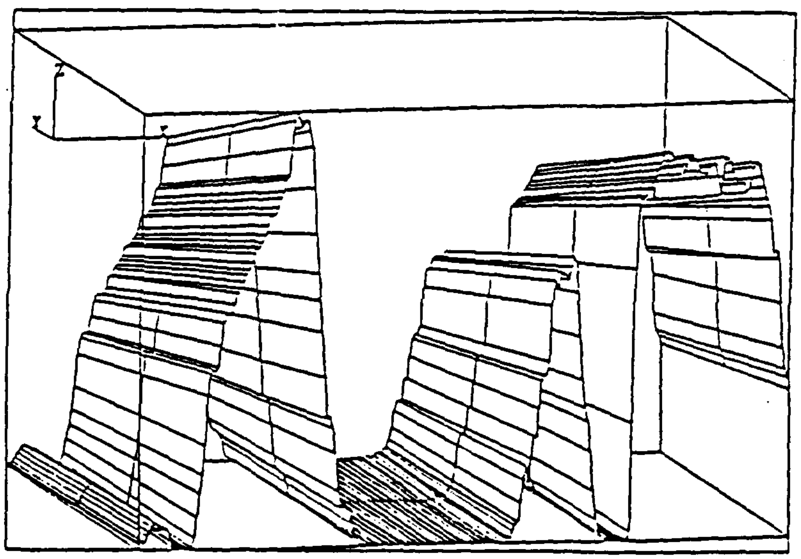


Figure 7. A typical picture of 3D plotting.

The numerical commands perform common arithmetic manipulations on the data set. 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's label is modified accordingly. For example, if the z-axis label is "TRANSMITTANCE", and you perform a log conversion on the z-axis, then the z-axis label will be "LOG TRANSMITTANCE". This change is reflected both on plots and on the command screen. The following table lists all of the numerical commands, along with a brief description of their action.

Table 4. List of numerical commands in GRAPH & ANALYZE.

COMMAND	ACTION
A2T	- The A2T command converts data set's Z values from optical depth to transmittance.
DX	- The DX command calculates the partial derivative of Z-Axis data with respect to the X-Axis.
DY	- The DY command calculates the partial derivative of Z-Axis data with respect to the Y-Axis.
DDX	- The DDX command calculates the 2nd order partial derivative of Z-Axis data w.r.t. the X-Axis.
DDY	- The DDY command calculates the 2nd order partial derivative of Z-Axis data w.r.t. the Y-Axis.
DYDX	- The DYDX command calculates the cross derivative, evaluating DY first.
DXDY	- The DXDY command calculates the cross derivative, evaluating DX first.
LOG[X,Y,Z]	- The LOG command converts all elements of the named vector to their log values. The "X" and/or "Y" and/or "Z" arguments are typed exactly as they appear. Omit the square brackets.
MAXIMUM	- The MAXIMUM command displays the (X,Y,Z) coordinate(s) of the maximal Z-Axis value(s) in the data set.
MEAN	- The MEAN command displays the average of the Z-Axis values according to Σ Z(i)/#points, i = 1 to #points.
MINIMUM	- The MINIMUM command displays the (X,Y,Z) coordinate(s) of the minimal Z-Axis value(s) in the data set.
NOSORT	- The NOSORT command provides a tool for suppressing SENTRAN's tendency to sort each axis by value. Instead, the data is plotted as encountered within the data set. See the SENTRAN TECHNICAL REFERENCE for more information.
T2A	- The T2A command converts the data set's Z values from transmittance to optical depth.
SWAP	- The SWAP command swaps the X-Y coordinates for all of the data points, effectively swapping the axes along which data are plotted.

The plotting commands provide you with a means to control certain aspects of the graphical presentation of the data set. The following table summarizes the plotting commands and provides a brief description of their actions.

Table 5. List of plotting commands in GRAPH & ANALYZE.

COMMAND	ACTION
TITLE [chart title]	- treats all subsequent text on the command line as the title of the next plot, and centers this text at the top of the chart.
XLABEL [x label]	- treats all subsequent text (up to 30 characters) as the X-Axis label.
YLABEL [y label]	- treats all subsequent text (up to 30 characters) as the Y-Axis label.
ZLABEL [z label]	- treats all subsequent text (up to 30 characters) as the Z-Axis label.
PLOT [file name] [VT240]	- initiates plotting of the data set. You 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. Also, the plot argument will cause the program to request rotation arguments. You 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 counterclockwise rotation about the original Z-Axis, while the second angle is counterclockwise rotation about the X-Axis (i.e. tilt out of the screen). See Figure 8 for details of axis and rotation conventions.

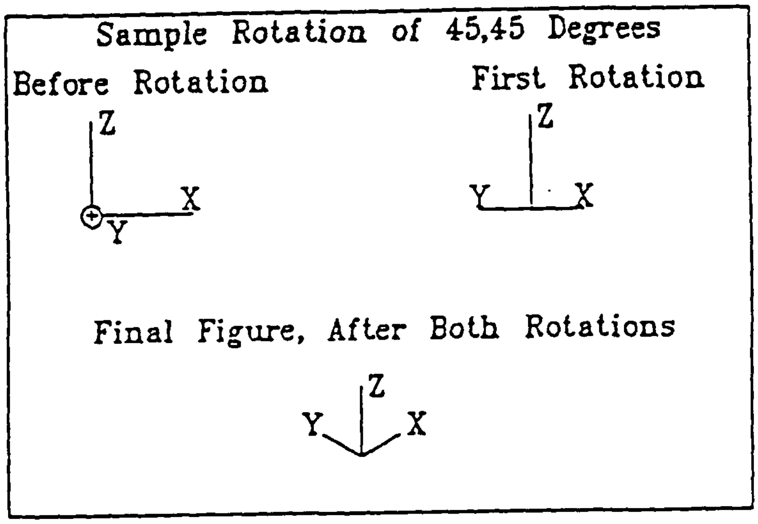


Figure 8. Conventions for axis and rotation for 3D plotting.

The I/O and control commands currently consist of five directives; WRITE, COSMETIC, NEW, EXIT, HELP and REFRESH. The following table summarizes these commands, describing any required arguments and outlining resultant actions.

Table 6. List of I/O and control commands in GRAPH & ANALYZE.

COMMAND	ACTION
WRITE [x,y,z data file]	- The write command accepts a file name as its argument, writing the data set to the named file in raw X,Y,Z format. SENTRAN adds the default extension ".3d" to the file name, unless the file name argument already contains an extension.
COSMETIC [cosmetic file]	- The COSMETIC command accepts a file name as its argument and writes a copy of the current command screen to the named file. SENTRAN adds the default extension ".COS" to the file name unless the file name argument already contains an extension.
NEW	- The NEW command re-initiates the G&A module and is used for restoring damaged data or selecting an

	alternative data set. After typing "NEW", you will need to go through the data input logic again before resuming command mode.
EXIT	- The EXIT command returns control to the main menu.
HELP [command name]	- The HELP command accesses the G&A online 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 available G&A commands. Do not confuse this command with the main menu HELP command (next section).
REFRESH	- The REFRESH command restores the G&A command screen in the event that it becomes corrupted (by a system message from another user for example).

II-2-5. HELP

The HELP module is the simplest of SENTRAN's main modules. The HELP command may be typed at the main menu screen with or without an argument. In the absence of an argument, a special introductory help screen appears, with a list of topics on which help is available. You may then enter the name of a selected topic, whereupon you will receive help on that particular topic. Alternatively, you may enter "*" in order to receive help on all available topics. If you do not select a topic, or you select an invalid topic, control will return to the main menu.

II-2-6. Miscellaneous

There are three simple commands accessible from the main menu, which are not displayed as main menu choices. These are the LOG, NOPROMPT and ZAP commands.

The LOG command writes all user input to a file named SEN.LOG. SENTRAN automatically enhances this file with comments which help you to determine the logical flow taken through SENTRAN, aiding you in interactive development and debugging of files for batch submission. SENTRAN displays the word LOG in the extreme upper left of the screen when the LOG feature is active.

The NOPROMPT command suppresses all writing to the screen. This feature is useful for batch submissions since screen output is unnecessary in such situations. NOPROMPT actually functions as a toggle. Therefore, if screen output is inadvertently disabled, it may be re-enabled by tying "NOPROMPT" a second time.

The ZAP command zaps all input decks, setting all LOWTRAN variables to 0 and eliminating all perturbation directives. The zap command is useful when you wish to make extensive revisions to LOWTRAN input decks; revisions which are so extensive that starting from scratch is simpler than editing all of the necessary variables.

III. FILE STRUCTURE

III-1. Introduction

There are several types of files associated with the SENTRAN/LOWTRAN system. These are as follows (* is a wild-card, indicating arbitrary text):

Table 7. File type structure.

File type	File name & ext.
Methodology files	*.MTH
LOWTRAN input decks	*.INP
LOWTRAN data output	*.OUT
SENTRAN raw X,Y,Z data	*.3D
SENTRAN graphics files	*.TEK
SENTRAN cosmetic data	*.COS
SENTRAN help files	*.HLP
SENTRAN error log & major absorber info	SEN.ERR
SENTRAN user input log	SEN.LOG
SENTRAN flag file	FLG.TRN
LOWTRAN layerwise change in trans. file	DTAU.DAT

This sort of file structure was carefully designed to permit all of the files associated with a given experiment (methodology, input, output, 3-D, graphics and cosmetic files) to share the same first name, simplifying the task of data management. Note that an upper limit of 20 characters (or less, if your system restricts) for a file name is silently enforced.

III-2. File Structure and Usage

The structure and usage of each type of file is discussed in detail here.

Methodology File

Methodology files, called MTH files, contain information necessary for loading the editing buffer with nominal values and perturbation directives. They provide a convenient means for saving input data for LOWTRAN experiments for later recall. MTH files are generally written and read via the LOAD/SAVE module, with the exception of a special file called "LAST.MTH". LAST.MTH is saved after every completed editing session (i.e. an editing session in which you do not proceed to the main menu via the END command) and every compilation. This file is loaded every time that SENTRAN is started. Since SENTRAN extracts vital information from this file, you are cautioned against tampering with it in any way.

Input File

Input files, called INP files, are files containing the LOWTRAN input decks. Naturally, INP files are generated by SENTRAN's COMPILE module. LOWTRAN must be slightly modified in order to accept named input decks. Directions for modifying LOWTRAN in this manner may be found in the "SENTRAN Programmer's Guide" and a version of LOWTRAN containing these modifications should be available on your SENTRAN distribution tape

Output Files

Output files (LOWTRAN TAPE7 type files) contain LOWTRAN generated data containing minimal cosmetic data, and are the files which SENTRAN uses to extract LOWTRAN data. LOWTRAN must be slightly modified in order to generate named output files. As with the modification for named input decks, directions for appropriate modification of LOWTRAN may be found in the "SENTRAN Programmer's Guide".

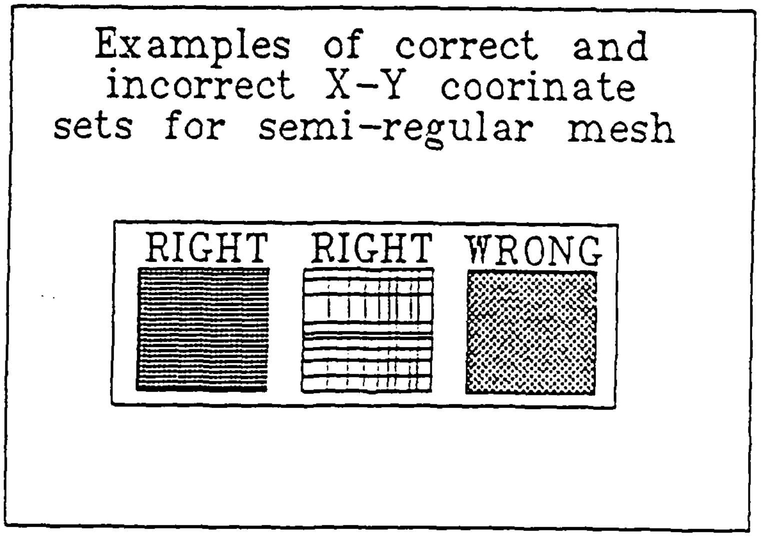


Figure 9. Example of a data set with semi-regular mesh.

3-D Files

3-D 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 (see Figure 9 above). 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 GRAPH & ANALYZE section of SENTRAN. It's worth noting that SENTRAN can read any file in X,Y,Z format which conforms to the specifications above. Thus SENTRAN's graphing and analysis capabilities are not limited to LOWTRAN 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, such as SAS.

Graphics File

Graphics files, called TEK files, consist of special escape sequences and character data, which may be interpreted by TEKTRONIX 4010/4014 compatible devices in order to generate graphics (for example, Digital Equipments Corporation 1984). 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.

Cosmetic File

Cosmetic files, called COS files, contain "cosmetic" information for 3D files. COS files are actually "snapshots" of the GRAPHICS & ANALYSIS command screen, providing information on the data source file, any numerical manipulations which have been performed, the most recent 3D file generated and the most recent TEK file generated, among other pieces of information.

Help File

Help files, identifiable by their .HLP extension, are text files containing help information for SENTRAN. SENTRAN uses these files internally in order to generate its help screens. You are cautioned against tampering with the help files, unless you are sure of what you're doing.

SEN.ERR File

The SEN.ERR file is devoted to debugging and temporary storage of information on major absorbers. If you compile input decks with the /ERROR option, SENTRAN will write 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.

SEN.LOG File

The SEN.LOG file is a product of SENTRAN's logging function. This function permits you to maintain a terse log of your SENTRAN sessions. SENTRAN automatically adds comments, which aid in determining the logical flow and which was taken through the program. You may replace these automatic comments with comments of your 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 SENTRAN. An example of development and submission of a batch run of SENTRAN in a VAX/VMS environment is included in the SENTRAN Programmer's Guide.

FLG.TRN File

FLG.TRN is a special file which is of little direct use to you. It provides SENTRAN with a special means of communicating with LOWTRAN, enabling SENTRAN to direct modified versions of LOWTRAN to perform special tasks (such as extraction of layerwise changes in transmittance). In normal operations, you are advised not to tamper with this interface.

DTAU.DAT File

The DTAU.DAT file is a file generated by specially modified versions of LOWTRAN. By making appropriate changes in LOWTRAN's TRANS subroutine (about 10 lines of code) it is possible to generate a file which contains information on layerwise changes in transmittance as calculated by LOWTRAN. Directions for this modification are contained in the SENTRAN Programmer's Guide. The modified version of LOWTRAN supplied on your distribution tape already contains these modifications.

IV. TUTORIALS

IV-1. Introduction

While the previous chapters provided a fairly general description of SENTRAN from a functional point of view, it does little in the way of teaching you to actually use SENTRAN. The following section of this manual will guide you through a series of brief exercises which should make you reasonably comfortable with using SENTRAN. It's important that you actually are using the program as you proceed through these tutorials, since they make little or no sense by themselves.

IV-2. Basic Concepts of User Interface

One of the chief features of SENTRAN is its flexible user interface, which permits you 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. **Do not forget about this command parsing feature!** It 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 investment required to learn the command driven syntax.

IV-3. Tutorials

As you proceed through the following tutorials, please keep the following conventions in mind:

- The text which you must enter will appear in boldface.
- You must press the RETURN 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 key".

TUTORIAL 1.1 Getting Started With LOAD/SAVE

The LOAD and SAVE commands permit you to retrieve and store LOWTRAN input parameters and directives for parameter variation. In the following tutorial, we will LOAD one of the methodology files which are supplied with your distribution tape, named CASE111R.MTH (see LOWTRAN5 manual, pg. 111, Fig. 28-a), and save it under the name FIRST.MTH, using both step-by-step and command techniques. Before starting this tutorial, invoke operation of SENTRAN. The following main menu should appear.

```
                WELCOME TO SENTRAN
    THE LOWTRAN SENSITIVITY ANALYSIS PROGRAM

                  1 - LOAD/SAVE

                  2 - EDIT

                  3 - COMPILE

                  4 - GRAPH & ANALYZE

                  5 - HELP

                  6 - QUIT

?
```

Figure 10. SENTRAN main menu screen.

TUTORIAL 1.1b Loading CASE111R.MTH

1) Type 1 at the above screen. The following screen should appear.

```
        SENTRAN METHOD FILE LOAD/SAVE

LOAD OR SAVE [FILENAME]:
```

Figure 11-a. SENTRAN LOAD/SAVE screen #1.

2) In response to the above prompt, type LOAD. The screen should appear as follows.

```
SENTRAN METHOD FILE LOAD/SAVE

LOAD OR SAVE [FILENAME] : LOAD

ENTER METHOD FILE NAME : ░
DEF. EXTENSION IS [.MTH]
```

Figure 11-b. SENTRAN LOAD/SAVE screen #2.

3) In response to the above prompt, type **case111r**. SENTRAN will load CASE111R.MTH and return to the main menu.

4) Now, repeat step 1 and type **load case111r** 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 case111r**. Note that we have accomplished the task of loading CASE111R.MTH in a single step.

TUTORIAL 1.1c Saving FIRST.MTH

Now that we have loaded CASE111R.MTH, its contents are in the editing buffer. The following steps will save these contents as a file named FIRST.MTH. Be sure that you have performed steps 1 through 3 in the above tutorial.

1) Type 1, invoking the LOAD/SAVE module.

2) In response to the prompt for "LOAD OR SAVE [FILENAME]", type **save**. The screen should appear as follows.

```
SENTRAN METHOD FILE LOAD/SAVE

LOAD OR SAVE [FILENAME] : SAVE

ENTER METHOD FILE NAME : ░
DEF. EXTENSION IS [.MTH]
```

Figure 11-c. SENTRAN LOAD/SAVE screen #3.

3) In response to the above prompt for a file name, type first. SENTRAN will have saved a new methodology file named FIRST.MTH which is identical to CASE111R.MTH. You may wish to verify this fact.

4) We can reduce the number of steps required to save FIRST.MTH by performing step 1 and typing save first at step 2.

5) We may reduce the number of steps further by typing save first at the main menu.

TUTORIAL 1.2 Editing FIRST.MTH

Since we have just generated a file named FIRST.MTH, its contents are still in our editing buffer. If you have not performed the steps in the first two tutorials, pease do so now, since it is important that the screens which SENTRAN presents are identical to those in this tutorial. Our 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) at a selected wavenumber of 1,300 cm-1 with MODEL=6 and IHAZE=1

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. Use these commands to move the cursor back to the line which is in error and type over your mistake.

1) Type either 2 or edit or some substring of edit (such as ed). The following screen should appear.

```
            SENTRAN EDITING UTILITY

                EDITING CARD 1

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

    MODEL *         1  2 4 6 3 5
    ITYPE *         0
    IEMSCT*         1
    M1 ...          0
    M2 ...          0
    M3 ...          0
    IM ...          0
    NOPRT *         0

FOLLOWING PARAMS. USE A PERTURBATION VALUE
```

```
    TBOUND              0.000000
    SALB                0.000000
```

Figure 12-a. SENTRAN EDITOR screen #1, CARD 1.

2) The cursor should presently be located on the line MODEL. We would like to use the 1962 U.S. Standard model, so type 6. After this value is entered, the line will reformat itself to reflect the change in data while the cursor moves to the next line.

3) Since the current line should be ITYPE, and we would like a horizontal path, type 0.

4) The active line should be IEMSCT at this point. We would like to calculate transmittance, so enter 0 at this point.

5) 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 the following:

```
          SENTRAN EDITING UTILITY

              EDITING CARD 1

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

    MODEL *             6
    ITYPE *             0
    IEMSCT*             0
    M1 ...              0
    M2 ...              0
    M3 ...              0
    IM ...              0
    NOPRT *             0

FOLLOWING PARAMS. USE A PERTURBATION VALUE

    TBOUND              0.000000
    SALB                0.000000


ALL PARAMETERS FOR CARD 1 O.K. (Y/N) [Y]
```

Figure 12-b. SENTRAN EDITOR screen #2, CARD 1.

6) 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" and make appropriate modifications to the card at this point.

7) Completion of CARD 1 and acceptance of its contents will move us to the CARD 2 screen, which should look as follows:

```
                 EDITING CARD 2

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

    IHAZE *      2
    ISEASN       0
    IVULCN       0
    ICSTL        0
    ICIR   *     0
    IVSA   *     0

FOLLOWING PARAMS. USE A PERTURBATION VALUE

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

Figure 12-c. SENTRAN EDITOR screen #3, CARD 2.

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

9) We will not need any further changes in CARD 2, so type pd to move on to the next card image. Once we have accepted the contents of CARD 2, the CARD 3 screen should appear, looking as follows:

```
                 EDITING CARD 3

FOLLOWING PARAMS. USE A PERTURBATION VALUE

    H1 ...       0.000
    H2 ...       0.000
    ANGLE        0.000
    RANGE        0.000
    BETA         0.000
    RO ...       0.000

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

```
LEN*            0
```

Figure 12-d. SENTRAN EDITOR screen #4, CARD 3.

10) H1 will be the first line in CARD 3. We would like to perturb this variable to assume all values from 0 to 20 inclusive in steps of 2. Therefore, type 0 to 20 step 2.

11) The next two parameters (H2 and ANGLE) will be ignored, since we are computing a horizontal path, so we can skip over them by typing dn2.

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

13) Our work on CARD 3 should be complete and we can proceed to CARD 4 by typing pd. Be sure that your CARD 3 screen has the following appearance:

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

    LEN*            0

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

Figure 12-e. SENTRAN EDITOR screen #5, CARD 3.

14) Our calculation is concerned only with a single frequency. Therefore, we can limit our spectral interval and realize a substantial savings in execution time and disk space. V1 should be the current variable, so type 1300. SENTRAN will reformat the line and present V1 in terms of cm-1 and microns.

15) For V2, enter 1305. LOWTRAN cannot calculate spectral

intervals with a span of 0.

16) For DV, type 5.

17) Your card should look as follows. If it does, accept its contents. If it does not, take the time now to fix it.

```
                 EDITING CARD 4

THE FOLLOWING PARAMS. CANNOT BE PERTURBED

    V1 ...     1299.99 CM-1    7.69 MICRONS
    V2 ...     1304.99 CM-1    7.66 MICRONS
    DV ...        5.000

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

Figure 12-f. SENTRAN EDITOR screen #6, CARD 4.

18) SENTRAN will now ask if you would like to extract DTAU values from LOWTRAN. We do not wish to do that in this experiment, since horizontal paths will not reflect the layerwise change in transmittance (only one layer at a time is calculated). Therefore we should press <RETURN>, accepting the default of "No, do not extract layerwise change in transmittance". This action concludes our editing tutorial.

TUTORIAL 1.3 Compiling

Now that we have edited FIRST.MTH we have a new methodology (let's call it SECOND.MTH) which we wish to compile as a LOWTRAN input deck.

1) At the main menu, type 3 or compile or any substring of "compile", such as com. The main menu should be replaced by a screen which looks like the following.

```
           DEVELOPING LOWTRAN INPUT DECK
           BASED ON LAST EDITING SESSION

LOWTRAN INPUT CARD NAME & OPTIONS ?
```

Figure 13-a. SENTRAN COMPILE screen #1.

2) In response to the prompt for a deck name and compile options, type second /m/e, meaning "compile a LOWTRAN input deck named SECOND.INP in MESH form with ERROR logging and automatically generate a .MTH file named SECOND.MTH". Alternatively, we could have combined steps 1 and 2 by typing compile second /m/e. In either case, the following screen should appear:

```
          DEVELOPING LOWTRAN INPUT DECK
          BASED ON LAST EDITING SESSION

LOWTRAN INPUT CARD NAME & OPTIONS ? SECOND/M/E

COMPILING SECOND.INP AS MESH ERRLOG
LIST OF ACTIVE ABSORBERS
   H2O IS ACTIVE OVER :
    1300.0 TO  1305.0
   UNIF.MIXED GASSES ARE ACTIVE OVER :
    1300.0 TO  1305.0
   OZONE IS ACTIVE OVER :
    1300.0 TO  1305.0
   H2O CONT. IS ACTIVE OVER :
    1300.0 TO  1305.0
   HNO3 IS ACTIVE OVER :
    1300.0 TO  1305.0

                  PRESS <RETURN> TO CONTINUE
```

Figure 13-b. SENTRAN COMPILE screen #2.

3) Press the <RETURN> key once you have finished reading the screen containing information on major absorbers.

4) At this point, we should be back at the main menu. It is our intent to quit SENTRAN and run LOWTRAN using our new input deck. Therefore, you should type 6 or quit or some substring of "quit", such as q. You must then enter the necessary commands to run LOWTRAN on your system. This action will generate a file named "SECOND.OUT" which we shall use in the next section for our tutorial on the GRAPH & ANALYZE module.

TUTORIAL 1.4 Graphing & Analyzing LOWTRAN data

Now that we have generated some LOWTRAN data, we can proceed to graph and analyze it. Be sure that you have performed the preceding tutorials and executed LOWTRAN so that your results will be consistent with those of this tutorial. Since the GRAPH & ANALYZE module is fairly versatile, this tutorial is a cursory overview at best. The best way to master the G&A module is by utilizing the online help utility and "playing" with LOWTRAN data sets.

1) Type 4 or GRAPH or some sub-string of "GRAPH", such as G. The following screen should appear.

```
    SENTRAN GRAPHICS & ANALYSIS MODULE

PLOT TYPE: 1) 3D-DATA  2) TRANSMITTANCE







?
```

Figure 14-a. SENTRAN GRAPH & ANALYZE screen #1.

2) We would like to plot a transmittance profile, so in response to the prompt for a plot type, enter a 2. This should cause the screen to appear as follows.

```
    SENTRAN GRAPHICS & ANALYSIS MODULE

PLOT TYPE: TRANSMITTANCE

X-AXIS : 1) WAVENUMBER  2) RANGE





?
```

Figure 14-b. SENTRAN GRAPH & ANALYZE screen #2.

3) We would like the X-AXIS to be RANGE, so enter a 2 in response to the X-AXIS prompt. The screen should now look as follows.

```
    SENTRAN GRAPHICS & ANALYSIS MODULE

PLOT TYPE: TRANSMITTANCE
```

```
X-AXIS : RANGE

Y-AXIS : 1) WAVENUMBER  2) H1



?
```

Figure 14-c. SENTRAN GRAPH & ANALYZE screen #3.

4) We would like the Y-AXIS to be H1, so enter a 2 in response to the Y-AXIS prompt. The screen should now have the following appearance.

```
    SENTRAN GRAPHICS & ANALYSIS MODULE

PLOT TYPE: TRANSMITTANCE

X-AXIS : RANGE

Y-AXIS : H1

WAVENUM.:  1299 TO  1304


WHICH WAVENUMBER?
```

Figure 14-d. SENTRAN GRAPH & ANALYZE screen #4.

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 a selected wavenumber, type 1300. The G&A module should then read the LOWTRAN data set and proceed to command mode. The screen should have the following appearance.

```
    SENTRAN GRAPHICS & ANALYSIS MODULE

PLOT TYPE: TRANSMITTANCE

X-AXIS    : RANGE

Y-AXIS    : H1
```

```
WAVENUM. :  1299

UNITS OF : 1)CM-1 2)MICRONS

?
```

Figure 14-e. SENTRAN GRAPH & ANALYZE screen #5.

6) At this point, SENTRAN will prompt you for the units in which frequency dependent data should be expressed (CM-1 or MICRONS). Select 1, for CM-1. Note that the selection of units will have little effect in this particular case and may seem to be a superfluous entry item. However, the units selected may have great impact when reading in radiance and irradiance data, since the values of radiance and irradiance calculations are strongly affected by the units in which they are calculated.

7) You will now be presented with a number of items which may be read from the LOWTRAN output file. The actual choices presented will vary according to the type of calculation which you are performing (based on IEMSCT's value). Confirm that the screen which you see on your terminal matches the following figure. We wish to plot TOTAL TRANSMITTANCE, so select item 1.

```
      SENTRAN GRAPHICS & ANALYSIS MODULE

PLOT TYPE: TRANSMITTANCE

X-AXIS    : RANGE

Y-AXIS    : H1

WAVENUM. :  1299

UNITS OF : CM-1

Z-AXIS : 1)TOTAL 2)H20 3)CO2 4)OZONE 5)N2 CONT. 6)H2O CONT.
        7)MOL.SCAT 8)AERO. 9)HNO3 10)ABS. 11)INTEG.AERO.ABS

WHICH TRANSMITTANCE?
```

Figure 14-f. SENTRAN GRAPH & ANALYZE screen #6.

8) The final step in data selection involves choosing the file from which to read the LOWTRAN TAPE7 data. Since we compiled our file as SECOND.INP, the LOWTRAN output file

should be called SECOND.OUT. SENTRAN assumes a ".OUT" extension, so just type second in response to the file name prompt. You have completed the data selection portion of the G&A module, and the program will now enter the G&A command mode, with the screen looking as follows.

```
        SENTRAN GRAPHICS & ANALYSIS MODULE

PLOT TYPE: TRANSMITTANCE         FILE NAME : SECOND.OUT

X-AXIS    : RANGE

Y-AXIS    : H1

WAVENUM.  :  1299

UNITS OF  : CM-1

Z-AXIS    : TOTAL TRANSMITTANCE


COMMAND ?
```

Figure 14-g. SENTRAN GRAPH & ANALYZE screen #7.

9) Try to obtain a list of available GRAPH & ANALYZE commands by typing HELP. A single <RETURN> will bring you back to the command mode.

```
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 your request below, or press <RETURN> to continue
```

Figure 15. SENTRAN HELP screen.

10) If you have a VT240 type terminal, try plotting the data by typing **plot vt240**. The cursor will move to a new field and request rotation angles. 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 as follows.

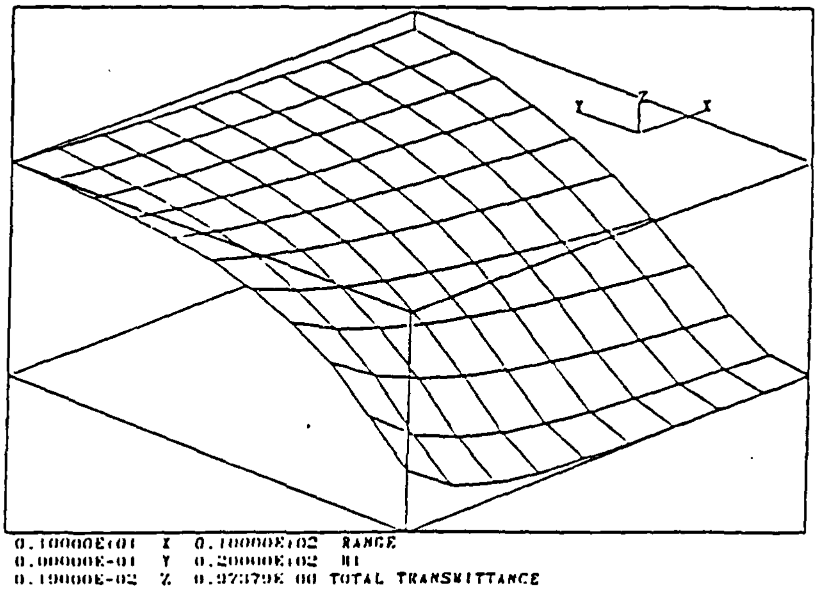


Figure 16. SENTRAN 3D plotting at 45 degrees rotation in both axes.

11) Press the <RETURN> key when you are done looking at the previous plot. Lets differentiate with respect to our X-axis by typing **dx**. Note that the program modifies the Z-axis label to reflect this manipulation. Let's plot the data set by typing **plot vt240**. Press the <RETURN> key to accept the default rotation arguments, which should be "45, 45". The resultant plot should look like Figure 17 on the next page.

12) Refresh your data set by typing **new** and re-answering all of the data input options.

13) Type **t2a** to convert the transmittance values to optical depth values. Type **PLOT VT240** and then 45,45 to see the results. They should look as Figure 18 on the next page.

14) Try seeing which commands are available by typing **HELP**. Experiment with the data set by trying as many of these commands as you can, using the online help whenever you have difficulties.

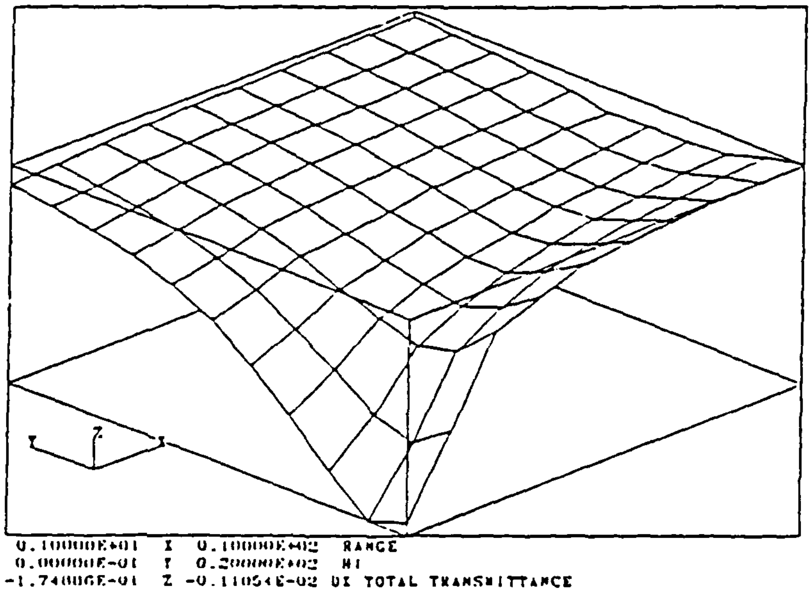


Figure 17. SENTRAN 3D plotting of derivative of transmittance with respect to the wavenumber (X-Axis), at 45 degrees rotation in both axes.

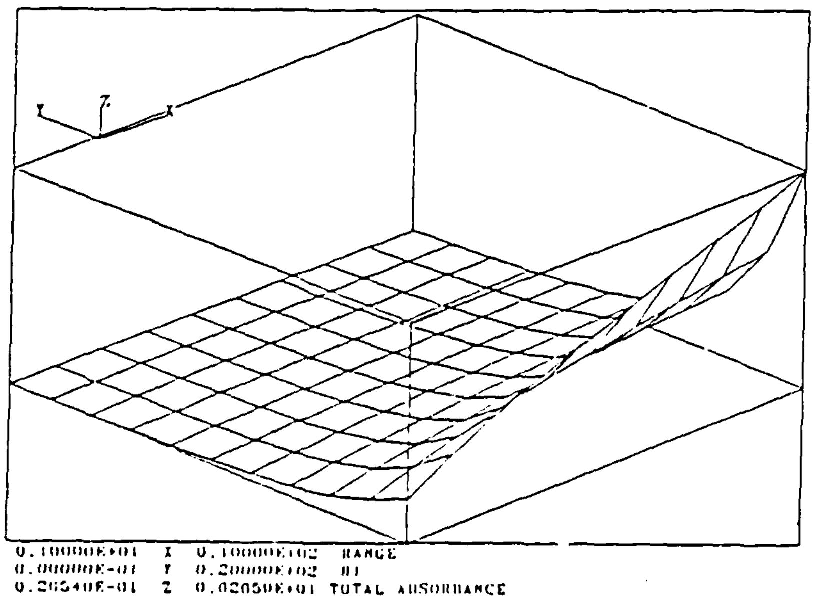


Figure 18. SENTRAN 3D plotting of optical depth at 45 degrees rotation in both axes.

This concludes the Tutorial section. The authors hope that their attempt in guiding the users over the "potential barrier" associated with the initial attempt of using a new software has been successful. We appreciate any comments associated with the contents of this manual.

REFERENCES

AT&T 1986. AT&T 3B2/3B15 Computer UNIX System V: FORTRAN-77 XLA+. (Especially, Appendix C-1 for bit manipulation.)

Digital Equipments Corporation 1984. VT240 Series - Programmer Reference Manual. (Especially, Chapter 10 for 4010/4014 Mode.)

Kneizys, F.X., E.P. Shettle, W.O.Gallery, J.H. Chetwynd, Jr., L.W. Abreu, J.E.A. Selby, R.W. Fenn, and R.A. McClatchey 1980. "Atmospheric Transmittance/Radiance: Computer Code LOWTRAN-5," Report AFGL-TR-80-0067, Air Force Geophysics Laboratory, Hanscom Air Force Base, Mass.

Kneizys, F.X., E.P. Shettle, W.O.Gallery, J.H. Chetwynd, Jr., L.W. Abreu, J.E.A. Selby, S.A. Clough, and R.W. Fenn 1983. "Atmospheric Transmittance/Radiance: Computer Code LOWTRAN-6," Report AFGL-TR-83-0187, Air Force Geophysics Laboratory, Hanscom Air Force Base, Mass.

Tomiyama, K., and M. Hogan 1988. "Sensitivity Evaluation Plan for LOWTRAN," Final Report, Contract Number F49620-87-C-0057, Air Force Office of Scientific Research, Bolling Air Force Base, Washington, D.C.

Appendix C. SENTRAN Technical Reference

Technical aspects of SENTRAN is discussed here in detail.

SENTRAN Technical Reference

Prepared for

The Air Force Office of Scientific Research
Bolling Air Force Base
Washington, D.C.

Under Contract Number

F49620-87-C-0057

Prepared by

Ken Tomiyama, and Michael Hogan
The Department of Electrical Engineering
Pennsylvania State University
University Park, PA 16802
(814) 865-7667

August, 1988

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

I. INTRODUCTION[1]

SENTRAN (Tomiyama and Hogan 1988) is a code which provides extremely efficient interactive analysis environment for LOWTRAN program (Kneizys et al. 1980, Kneizys et al. 1983). The SENTRAN Technical Reference is designed to provide a complete guide to all technical aspects of SENTRAN which do not require actual knowledge of the system's source code. To this end, this technical reference contains the following:

- a guide to installing and testing SENTRAN
- a summary of SENTRAN commands in quick-reference format
- a list of known bugs
- a trouble shooting guide

This guide should provide you with enough information to determine exactly what SENTRAN can and cannot do, helping you to exercise the program to its fullest. The necessary information for actually extending SENTRAN's capabilities (via re-coding the program) is contained in the SENTRAN Programmer's Guide. SENTRAN User's Guide & Tutorial should be consulted for introductory information on how to use SENTRAN.

---

[1] This manual was prepared as an appendix to the final report, Sensitivity Evaluation Plan for LOWTRAN.

II. INSTALLATION AND TESTING

II-1. Installing SENTRAN

This section is meant to assist in the task of installing SENTRAN and verifying its proper operation. You should present a copy of this section to your site manager, since it contains vital information on the distribution tape's format and the program's size requirements.

Note that SENTRAN is a reasonably large system which is capable of producing enormous quantities of data in a short time. SENTRAN requires approximately 1 megabyte of disk space for storing the complete system along with several user generated methodologies, 3D data files and TEK files. An additional 5 megabytes (minimum) of temporary disk storage is required for undertaking any serious analysis problems.

SENTRAN is distributed in one of three formats:

1) 1/2 " magnetic tape , 1600 BPI, encoded as a VAX *backup* save set (useful only on VAX sites)

2) 1/2 " magnetic tape, 1600 BPI, ASCII, RECORDSIZE=132, BLOCKSIZE=4356, NOLABEL. The first file will be a directory.

3) A set of floppy disks, MS-DOS format, 354 kbytes/disk.

Some systems permit files to be transferred from a PC, using special protocols to insure against errors. If your system has such capabilities, then 3) may be the best distribution format for you.

Once the SENTRAN system text has been transferred to your system, check to see that the files in the following table exist. If all of the files appear to be intact, proceed with compilation of SENTRAN and the modified version of LOWTRAN which has been supplied. FORTRAN77 compiler with DOD supplement (for example, AT&T 1986) should be used for this process. Provided that the compilation of SENTRAN is successful, users can proceed to the testing stage.

Table 1. File Checklist

* FORTRAN FILES

SENTRAN.FOR	LOWTRAN.FOR		

* ATMOSPHERIC PROFILE FILES

MODEL1.PRO	MODEL2.PRO	MODEL3.PRO	
MODEL4.PRO	MODEL5.PRO	MODEL6.PRO	

* METHODOLOGY FILES

CASE111T.MTH	CASE111R.MTH	DTAU.MTH	

* 3D DATA FILES

SAMPLE1.3D	SAMPLE2.3D	SAMPLE3.3D	

* SENTRAN HELP FILES

ANLZ.HLP	COMP.HLP	COSM.HLP	DIFF.HLP
EDIT.HLP	EXIT.HLP	GRPH.HLP	HELP.HLP
LABL.HLP	LOAD.HLP	LOG.HLP	LOG2.HLP
MAXI.HLP	NEW.HLP	NSRT.HLP	PLOT.HLP
RFRS.HLP	SAVE.HLP	SWAP.HLP	T2A.HLP
TITL.HLP	WRIT.HLP	ZAP.HLP	

* MISCELLANEOUS FILES

FLAG.TRN	SEN.LOG		

* DCL FILES (supplied only with VAX distribution tapes)

DTMOD.COM			

II-2. Testing SENTRAN

In order to test SENTRAN, you will need the following:

- an installed SENTRAN system
- an ANSI compatible terminal[2]
- a TEKTRONIX 4010/4014 compatible graphics device (terminal, plotter etc.)[2]

Turn to TUTORIAL 1 in the SENTRAN User's Guide & Tutorial and perform most or all of the exercises within the tutorial. If the program behaves as advertised, you can be reasonably confident that SENTRAN has been installed correctly and that it is compatible with your system.

[2] Refer, for example, Digital Equipment Corporation 1984.

III. COMMAND SUMMARY

III-1. Conventions Used

In diagramming commands, the following conventions are used (the important aspects of command diagramming appear in bold print for easy scanning):

- **The command will appear along the left column in capital letters.** The first several characters will appear in bold type. You must, at a minimum, **type the bold portion of the command exactly as it appears** in order to have the command execute.
- A list of valid arguments will follow the command.
- Abstract descriptions of **variable arguments** will appear as **underlined text,** in lower case. **Type the appropriate substitute for the underlined text.** For example an argument represented as methodology file name should be entered as an actual methodology file name, such as CASE111T.MTH.
- Literal descriptions of **fixed arguments** appear in lower case **to the right of the command.** The first several characters of the fixed argument will appear in bold type. You must, at a minimum, **type the bold portion of the fixed argument exactly as it appears** in order for the argument to be recognized.
- Optional arguments will appear in square brackets. **Do not type the square brackets which appear in the command description.**
- **Mutually exclusive arguments** will appear **one above the other.**
- A short paragraph providing a further description of the command may accompany the command description.
- One or more examples of actual command usage may follow the command description.

As an example of the command description format described above, consider the description for the command "COMPILE". This entry tells you that you must, at a minimum, type "C" followed by the name of the input deck which you wish to generate. There are three optional arguments after the file name, whose minimal expressions are "/m", "/n" and "/e" respectively. The "/m" and "/n" options are mutually exclusive.

```
COMPILE input file name  [/nomesh] [/error]
                         [/mesh]
```

Figure 1. Example of a command description entry.

III-2. Main Menu Commands

III-2-1. Main Menu Commands Chosen by Name

All of the commands accessible from the main menu may be accessed by name or by number, with the three invisible commands (ZAP, LOG and NOPROMPT) being exceptions. They are accessible only by name. The authors feel that access by name is the preferred method, since command names are mnemonics for the action being performed and are somewhat intuitive, easing the task of learning the program. Further, access by name makes LOG files much simpler to decipher. The following section details "named" usage of main menu commands.

ANALYZE

The ANALYZE command (no arguments) transfers control to the GRAPHICS & ANALYSIS (G&A) module. Its function is identical to the GRAPH and 4 commands. After entering the ANALYZE command, you will be presented with a series of questions regarding the source of the data which you would like to analyze. Once you respond to these questions, SENTRAN will load the requested data and enter the G&A command mode, permitting you to manipulate and plot the data set. For a synopsis of G&A commands see Section III-4.

COMPILE input file name [/nomesh] [/error]
[/mesh]

The COMPILE command is used to generate a LOWTRAN input deck, based on the information which is currently within the editing buffer. The default mode for compilation (MESH or NOMESH) is based on the last mode used. The default extension for the file name is ".MTH". Users may override the default file name extension by explicitly adding their own extension.

EXAMPLES

COMPILE TEST /MESH /ERROR	Develops a LOWTRAN input deck named TEST.INP in MESH format and writes all information on major absorbers to the SEN.ERR file.
COMPILE	System will prompt for file name and compile option arguments. If you respond TEST /M /E then the result will be the same as the first example.

EDIT .

The EDIT command (no arguments) causes the program to enter the EDITING utility, providing a means of editing LOWTRAN input variables and directives for their perturbation. See the <u>SENTRAN User's Guide & Tutorial</u> for conceptual information on the EDITOR module. Also, see Section III-3 for a synopsis of valid editing commands.

GRAPH

The GRAPH command (no arguments) invokes the GRAPHICS & ANALYSIS (G&A) module. After typing GRAPH, you will be asked to make a number of choices regarding you data source. Once these questions have been answered, the program will enter the G&A command mode, permitting you to enter commands for manipulating and plotting the data set. See the <u>SENTRAN User's Guide & Tutorial</u> for a conceptual overview of the GRAPH & ANALYZE section of the program. Also, see Section III-4 for a summary of G&A commands.

HELP [<u>command name</u>]
[*]

The HELP command is designed to provide on-line help for SENTRAN users. The HELP command optionally accepts main menu commands as arguments, providing help on that command. In the absence of a valid argument, the HELP module will display an introductory help screen listing all of the available SENTRAN commands, and will provide the user with an opportunity to obtain help on one of the displayed commands. A special reserved argument, "*", will display help on all of the main menu commands.

EXAMPLES

HELP EDIT	Provides help on the EDITOR module.
HELP	Provides a special help screen listing all available commands. Typing EDIT then will yield the same response as the previous example.
HELP *	Provides help on all topics.

LOAD <u>methodology file name</u>

The LOAD command provides a means of loading methodology files. You may optionally type the methodology file name behind the LOAD command. If you do not include the methodology file name with the LOAD command, an additional prompt will be issued for the file name, which should be entered before returning to the main menu. Failure to enter a file name, or non-existence of a file results in a "no-action" response.

EXAMPLES

LOAD TEST	Loads a methodology file named TEST.MTH into the editing buffer.
LOAD	Causes program to prompt for a methodology file name. If you respond TEST, then the effect will be exactly the same as the preceding example.
LOAD WIERD.EXT	Loads a file named WIERD.EXT, demonstrating that users can override the default file name extension for the methodology files.

LOG

The LOG command (no arguments) toggles the SENTRAN input logging function. When the LOG function is active, the word LOG appears in the extreme upper left-hand corner of the screen, indicating that all user entries (enhanced with automatic comments) are being written into the SEN.LOG file. Note that the LOG command must be typed in its entirety in order to avoid conflicts with the LOAD command.

NOPROMPT

The NOPROMPT command provides a means for suppressing the program's screen output. This is a valuable tool for batch submission of SENTRAN, since screen output is often unnecessary or undesirable in such situations. The NOPROMPT command functions as a toggle, and it may be used to switch screen output on and off at will. The NOPROMPT command must be type in its entirety.

QUIT

The QUIT command causes SENTRAN to stop execution in a graceful manner. Your particular system may provide other means for killing a program interactively. For example, on VAX/VMS systems the CONTROL-C and CONTROL-Y character will interrupt the program's execution. This may be helpful if you get "stuck" within some portion of the program. However, these methods of terminating execution are "brute force" techniques and should be avoided if possible. The QUIT command is the preferred method for terminating program execution.

SAVE <u>methodology file name</u>

The SAVE command provides a means of saving the contents of the editing buffer in the form of a methodology file. You may optionally type the file name behind the SAVE command. If you do not include the methodology file name with the SAVE command, an additional prompt will be issued for the file name. Failure to enter a file name will result in a "no-action" type of response.

EXAMPLES

SAVE TEST	Saves a methodology file named TEST.MTH.
SAVE	Transfers control to the LOAD/SAVE screen, whereupon the program prompts you for a file name. If you type TEST then, the result will be identical to the previous example.

ZAP

The ZAP command (no arguments) "zaps" all of the LOWTRAN card images, setting all values to zero. The ZAP command is useful when it is necessary to make such extensive revisions that starting from "scratch" is easier than modifying all of the necessary variables. One danger of the ZAP command is that it sets the spectral interval such that V1=V2=0.0; a condition which will cause LOWTRAN to crash.

III-2-2. Main Menu Commands Chosen by Number

All of the MAIN MENU commands which are listed by number may be accessed by their menu numbers as well as by name. Access by number is generally less efficient than access by name. It bypasses the mnemonic reinforcement which access by name provides, possibly impeding the process of learning the program and increasing the likelihood of user error. However, some users may be accustomed to "numerical menus" and may have a preference for them. This section details the usage of main menu commands accessed by number.

1 [save] [methodology file name]
[load]

When entered from the main menu, 1 invokes the LOAD/SAVE module. You may optionally imbed the commands "Save" or "Load" behind the command "1" and you have the option of following the "Save" or "Load" argument with the name of the methodology file which you wish to save or load. A ".MTH" extension is presumed in the file name unless an extension is explicitly supplied. While the "1" command accepts arguments, it's chiefly designed for step-by-step invocation of the Load or Save routine. See the entries under "SAVE" and "LOAD" in the previous section for a more direct means of loading and saving methodology files.

EXAMPLES

1	Transfers control to the LOAD/SAVE module. You will then be prompted to enter a file mode (LOAD or SAVE) and an optional file name. If you do not supply a file name at this first prompt, you will receive a second prompt, requesting a file name.
1 SAVE	Transfers control to the LOAD/SAVE module and requests that you enter the name of the methodology file to be saved.
1 LOAD	Transfers control to the LOAD/SAVE module and requests that you enter the name of the methodology file to be loaded.
1 LOAD TEST	Bypasses all prompts, loading a methodology file named TEST.MTH. However, this syntax is inefficient, since typing "LOAD TEST" or even "L TEST" will accomplish the same thing.

2

When entered from the main menu, 2 (no arguments) invokes the EDITOR module, providing a means of editing LOWTRAN input variables and directives for their perturbation. The 2 command is identical to the EDIT command. See the SENTRAN User's Guide & Tutorial for conceptual details of the editing module. Also, refer to Section III-3 for a list of cursor control commands.

3 [input file name] [/nomesh] [/error]
[/mesh]

The command 3, when entered from the main menu, will invoke the COMPILER module, generating LOWTRAN input decks based on the values and perturbation directives currently contained in the editing buffer. The 3 command is identical to the **COMPILE** command outlined in the previous section.

EXAMPLES

3 TEST /MESH /ERROR	Develops LOWTRAN input deck named TEST.INP in MESH format and writes all information on major absorbers and compile time errors to the SEN.ERR file.
3	System will prompt for arguments. If you respond **TEST /M /E** the result is the same as the first example.

4

Typing **4** at the main menu causes the program to transfer control to the GRAPHICS & ANALYSIS module. You will be asked to make several choices regarding your data sources. Upon completion of data source selection, SENTRAN will read the requested data and pass control to the G&A command mode, permitting you to manipulate the data set. **4** is identical to the GRAPH and ANALYZE commands. See the <u>SENTRAN User's Guide & Tutorial</u> for a conceptual overview of the GRAPH & ANALYZE section of the program. Also, see Section III-4 for a synopsis of G&A commands.

5 [<u>command name</u>]

Typing 5 at the main menu invokes the HELP module. If the 5 command is typed with a SENTRAN command name as an argument, then help is provided on that command. If no argument is supplied, then a special introductory help screen containing all of the valid SENTRAN main menu commands is displayed. You are then given an opportunity to select one of these commands. The reserved argument "*" will cause the HELP module to display all the available commands on SENTRAN's main menu. The 5 command is identical to the HELP command described in the previous section.

6

Typing 6 (no arguments) at the main menu causes SENTRAN to quit gracefully. Its function is identical to the QUIT command. Your system may also support commands which will allow you to interactively kill a program in progress. For example, VAX/VMS systems will kill a program upon receiving a CONTROL-C or CONTROL-Y character. Such interactive kill techniques may be useful if you become lost within the program, but the QUIT or 6 commands are the preferred methods for terminating program execution.

III-3. Editing Commands

The Editing Commands are a set of commands which are active only in the EDITOR module. Editing Commands are useful for directing the editor to perform special functions, such as moving from variable to variable within a card. This section lists all of the EDITING commands and describes their effects.

DN [n]

The DN command moves the editing cursor down n lines. The n argument is optional and its absence implies n=1. If the "DN n" command causes the cursor to move beyond the bottom of the card image, then the effect is identical to a "PD" command, causing SENTRAN to move to the next LOWTRAN card image. The DN command causes the line which is currently active to remain unchanged.

EXAMPLES

dn 6	Causes the cursor to move down 6 entries within the current card image.
dn	Causes the cursor to move down 1 entry within the card image. This is inefficient, since merely pressing the <RETURN> key will have the same result.

PD

The PD command (no arguments) causes the editor to move to the next LOWTRAN card image in the card image sequence. The PD command has no effect on the text contained in the line from which the command was issued.

PU

The PU command (no arguments) causes the editor to move to the previous LOWTRAN card image in the card image sequence, provided it exists. The PU command has no effect upon the line from which it was issued.

UP [n]

The UP command causes the editor to move up n entries within the current card image. The n argument is optional and its absence implies n=1. If less that n previous entries exist within the current card image, then the effect will be identical to the PU command.

*

The "*" command is unique, in that it is the only SENTRAN command which **must be preceded by a number.** The function of the "*" command is to permit you to change the nominal value of a LOWTRAN input variable, but keep the old perturbation, thereby saving you the trouble of re-typing the old perturbation directive.

EXAMPLE

10 *	Change the nominal value on the current line to 10, but keep the old perturbation directive.

III-4. GRAPHICS & ANALYSIS Commands

The GRAPHICS & ANALYSIS (G&A) commands permit interactive manipulation and plotting of the data within SENTRAN's data buffer. The G&A module is fairly complex, having more commands than all other portions of the program combined. The following section lists the G&A commands in alphabetical order and outlines their usage. Additional information may be found in the <u>SENTRAN User's Guide & Tutorial</u>.

A2T

The A2T command (no arguments) transforms the Z-Axis data according to Z=exp(-Z). While the mnemonic for the A2T command is "Absorbance TO Transmittance", the transformation is more properly called an "OPTICAL DEPTH to TRANSMITTANCE" conversion, in deference to the terminology used in the LOWTRAN literature.

COSMETIC <u>cosmetic file name</u>

The COSMETIC command causes a "snapshot" of the current G&A command screen to be written to the named file. This provides some documentation on the contents of SENTRAN's data buffer and any transformations to which it has been subjected. The COSMETIC command provides a means of documenting .TEK, .3D, and .OUT files without corrupting their contents.

DDY

The DDY command (no arguments) computes the second partial derivative of the data set with respect to the Y-Axis.

DDX

The DDX command (no arguments) computes the second partial derivative of the data set with respect to the X-Axis.

DY

The DY command (no arguments) computes the partial derivative of the data set with respect to the y axis.

DYDX

The DYDX command (no arguments) computes the cross derivative of the data set, evaluating the partial derivative of the data set with respect to the Y-Axis before evaluating the partial derivative of the data set with respect to the X-Axis. While the data set is presumed to be a surface, implying DYDX=DXDY, numerical differentiation is slightly sensitive to commutation of the axes. The greatest discrepancy usually occurs at the first point of the data set, Z(XMIN,YMIN).

DX

The DX command (no arguments) causes the program to compute the partial derivative of the data set with respect to the X-Axis.

DXDY

The DXDY command (no arguments) causes the program to compute the cross derivative of the data, evaluating the partial derivative with respect to the X-Axis before evaluating the partial derivative with respect to the Y-Axis. See the DYDX entry for notes on the effects of axis commutation.

EXIT

The EXIT command exits the G&A module, returning control to the main menu.

LOG [x][y][z]

The LOG command transforms all coordinates of the named axis to their natural log values. The LOG command first checks the data set for non-negativity before performing this action. It issues an error message if this constraint is violated. If there are any 0 valued elements in the named axis, they are presumed to be underflows and are given the value log(AXMIN/2.), where AXMIN is the smallest non-zero element of the data set.

EXAMPLE

LOG X	Converts all X coordinates to their log values.

MAXIMUM

The MAXIMUM command (no arguments) causes the maximal Z-values to be written to the screen, along with their X,Y coordinates. Note that the maximal Z values may be non-unique. In light of this fact, the MAXIMUM command causes the maximal Z values to be displayed in a page-by-page format. After each page of values has been displayed, you may continue to the next page by pressing the <RETURN> key, or you may quit by entering "Q".

MEAN

The MEAN command (no arguments), computes and displays the mean Z-Axis value. If there are no data points in the buffer, the MEAN command will result in an error message.

MINIMUM

The MINIMUM command (no arguments) is similar to the MAXIMUM command, computing and displaying the minimal Z-values along with their X,Y coordinates. Note that the minimal Z values may be non-unique. In light of this fact, the MINIMUM command causes the minimal Z-values to be displayed in a page-by-page format. After each page of values has been displayed, you may continue to the next page by pressing the <RETURN> key, or you may quit by entering "Q".

NEW

The NEW command transfers control to the data source selection portion of the G&A module (i.e. the section of the program which executes immediately upon entry into the G&A module). The NEW command is especially useful for extracting different sub-sets of a LOWTRAN output file, or for restoring a corrupted data set.

NOSORT [x][y]

The NOSORT command suppresses SENTRAN's tendency to sort data according to its value. Instead, data on the "unsorted" axis is plotted in the same order as is encountered within the data set. This is especially useful for plotting discrete values when you wish to control their orientation within the data set. Note that it is impossible to differentiate reliably with respect to the unsorted axis. This should be no great inconvenience since such a calculation makes no physical sense.

EXAMPLES

nosort y	Forces SENTRAN to order the Y-axis data in the order in which is read from the source file.

PLOT [file name][vt240]

The plot command causes SENTRAN to plot the data set which currently occupies the data buffer. The plot command accepts a file name as an argument, presuming a .TEK extension for the file name. An additional reserved argument, "VT240", will cause graphical output to be sent to the screen, provided your terminal is VT240 compatible. If no argument is supplied, the plot command will have no effect.

EXAMPLES

plot vt240	Causes graphics to be sent to the terminal.
plot demo	Causes graphics to be written to a file named DEMO.TEK.
plot test vt240	Causes graphics to be written to a file named TEST.TEK while simultaneously plotting the graphics on your terminal.

REFRESH

The REFRESH command (no arguments) redraws the G&A command screen, in the event that it becomes corrupted.

SWAP .

The SWAP command (no arguments) exchanges each X and Y coordinate within the data set, effectively swapping the X and Y axes.

TITLE [plot title]

The TITLE command causes all of the following text in the input line to be treated as a title for subsequent plots, centering the string at the top of the plotting screen. The title is forced to upper case.

EXAMPLE

title This Is Mixed Case	Will cause the text "THIS IS MIXED CASE" to appear at the top of the chart

T2A

The T2A command (no arguments) converts the Z-Axis data from transmittance to optical depth, according to the formula Z=log(1/Z) provided the current data set is transmittance. If the data set is not transmittance, the T2A command will cause an error message to be issued.

WRITE [X,Y,Z file name]

The WRITE command writes the current data set to the named file as raw X,Y,Z data. The default extension of .3D will be given to X,Y,Z data files.

EXAMPLES

write demo	Writes the current data set to a file named DEMO.3D.

XLABEL [X-Axis label]

The XLABEL command treats all following text (up to 30 characters) as the X-Axis label, and modifies the X-Axis label accordingly. The X-Axis text is forced to upper case. This command should not be used without a little forethought, since the X-Axis label may contain important information regarding earlier transformations of the X coordinates.

EXAMPLES

xlabel This Is Mixed Case	Will cause the X-Axis label to read "THIS IS MIXED CASE".

YLABEL [Y-Axis label]

The YLABEL command is identical to the XLABEL command, except that it is used for modifying the Y-Axis label.

ZLABEL [Z-Axis label]

The ZLABEL command is identical to the XLABEL command, except that it is used for modifying the Z-Axis label. There is a special danger in using the ZLABEL command, in that the T2A and A2T commands use the Z-Axis label as a means of checking whether the data set is suited to an optical depth <--> transmittance conversion. The ZLABEL command tends to circumvent this checking mechanism.

IV. LIST OF KNOWN LIMITATIONS[3]

SENTRAN is a large system which embodies fairly ambitious goals, developed under strict time limits. Therefore, it is natural that the system is less than perfect. However, most of these bugs are minor and have little negative impact on the usefulness of the code.

IV-1. Rounding Problems in Output Format Routine

SENTRAN utilizes internal character manipulation routines which mimic FORTRAN format statements, permitting flexible reformatting and mixing of character and numerical data. Often, when displaying a number, SENTRAN will display it incorrectly. SENTRAN terminates the number with a set of trailing 9's. For example the value 70 may be displayed as 69.99. While this problem may be disconcerting (i.e. the number which you type is not the number which you observe) the internal representation of the number is correct and the bug can safely be ignored.

IV-2. Program Fails to Read In Data for Certain Spectral Intervals

This problem is attributable to the fact that SENTRAN fails to emulate LOWTRAN's logic with respect to rounding of V1, V2 and DV. Therefore, upon reading the data set, SENTRAN will detect a mismatch in the spectral interval and will quit reading the data set. This error is easily avoided by insuring that (V2-V1)/DV is an integer.

IV-3. 2D Plotting Lacks Versatility

The 2D plotting capability was added as an "afterthought". This should present no great hardship, since the 2D plotting capabilities of LOWPLT work quite well. SENTRAN, on the other hand, is optimized for 3D surface plots.

IV-4. Axis Swapping Fails to Swap Axis Labels

This is a simple bug which will soon be fixed.

---

[3] This section contains a list of known bugs at the time of initial delivery of the SENTRAN code (August 3, 1988).

IV-5.. Nomesh Data Reading Works Poorly

Importation of data from LOWTRAN TAPE7 files in NOMESH form does not currently realize the full potential of the NOMESH format. Currently, only one perturbed parameter can be successfully extracted from a NOMESH output file. Therefore, there is no advantage in using the NOMESH format when using SENTRAN as a closed system. However, the NOMESH option may be useful for generating LOWTRAN data which will be used in other contexts, especially since there is no upper limit on the number of distinct values which a NOMESH perturbed parameter may assume.

IV-6. Only 1 DTAU File May Be Generated at A Time

It was originally hoped that SENTRAN could display various changes in the DTAU data as a function of perturbed parameters. However, time did not permit the full development of this capability. Therefore, only 1 DTAU extraction may be performed for each run. Revised versions of SENTRAN should fully develop this DTAU extraction capability.

V. TROUBLE SHOOTING GUIDE

This section shows common problems and their suggested solutions in tabular form.

PROBLEM	SUGGESTED SOLUTIONS
Unable to extract DTAU data	- Is IEMSCT=1 or 2? - Does the optical path pass through several layers? - Did you select EXTRACT DTAU after editing card 4?
Plot has no structure	- Extinction is probably too high or too low, hence transmittance values are all 1 or 0. Check input climatological values, etc.
Error Reading a TAPE7 file	- The methodology which is currently in the editing buffer may not match the TAPE7 file. Load the methodology which was used to produce the TAPE7 file. - The spectral interval may not satisfy (V2-V1)/DV = integer. Modify V2, V1, and DV.
Unable to access a CARD IMAGE or a variable within a CARD IMAGE	- The variable or card may be "locked out", since SENTRAN emulates LOWTRAN's logic flow through input decks. Check flag variables in preceding decks to see that they are not restricting access to the variable.
Results of calculation based on external model do not match results based on internal LOWTRAN model	- There are several calculations within LOWTRAN which are based on the model number, often causing discrepancies between internal and external models. It has been found that most of these discrepancies can be overcome by manually setting M1, M2 and M3 to match the external model number. For example, if calculations are based on MODEL1.PRO then M1,

M2, and M3 should each have the value 1.

REFERENCES

AT&T 1986. AT&T 3B2/3B15 Computer UNIX System V: FORTRAN-77 XLA+. (Especially, Appendix C-1 for bit manipulation.)

Digital Equipments Corporation 1984. VT240 Series - Programmer Reference Manual. (Especially, Chapter 10 for 4010/4014 Mode.)

Kneizys, F.X., E.P. Shettle, W.O.Gallery, J.H. Chetwynd, Jr., L.W. Abreu, J.E.A. Selby, R.W. Fenn, and R.A. McClatchey 1980. "Atmospheric Transmittance/Radiance: Computer Code LOWTRAN-5," Report AFGL-TR-80-0067, Air Force Geophysics Laboratory, Hanscom Air Force Base, Mass.

Kneizys, F.X., E.P. Shettle, W.O.Gallery, J.H. Chetwynd, Jr., L.W. Abreu, J.E.A. Selby, S.A. Clough, and R.W. Fenn 1983. "Atmospheric Transmittance/Radiance: Computer Code LOWTRAN-6," Report AFGL-TR-83-0187, Air Force Geophysics Laboratory, Hanscom Air Force Base, Mass.

Tomiyama, K., and M. Hogan 1988. "Sensitivity Evaluation Plan for LOWTRAN," Final Report, Contract Number F49620-87-C-0057, Air Force Office of Scientific Research, Bolling Air Force Base, Washington, D.C.