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HARPX--A PROGRAM TO EXTEND HARPO OR HARPA RAY PATHS IN HORIZONTALLY UNIFORM MEDIA

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CONTENTS

HARPX--A PROGRAM TO EXTEND HARPO OR HARPA RAY PATHS IN HORIZONTALLY UNIFORM MEDIA

ABSTRACT. We describe a FORTRAN computer program HARPX that can extend ray paths in horizontally uniform media if the ray paths have been calculated by either ray tracing program HARPO or HARPA. The HARPX program extends HARPO or HARPA ray path calculations that have been made for two or three ray loops (hops) in a horizontally uniform medium to more loops and correspondingly longer ranges. The input is a HARPO or HARPA rayset file, and the output is a another rayset file. The HARPX program extends the calculations in range by adding complete ray cycles to both odd and even ray loops. A floppy disk containing the program and sample input data is included.

1. INTRODUCTION

For horizontally uniform media (such as a uniform ocean sound channel), it is time consuming, costly, and wasteful to use a fully three-dimensional ray tracing program such as HARPO (Jones et al., 1986b) or HARPA (Jones et el., 1986a) when every ray loop would be the same. In such a case, it is more efficient to use HARPO or HARPA to calculate only enough of the ray path to determine the whole ray path for a horizontally uniform medium.

2. WHAT HARPX DOES

The HARPX program extends HARPO or HARPA ray path calculations that have been made for two or three ray loops (hops) in a horizontally uniform medium to more loops and correspondingly longer ranges. The input is a HARPO or HARPA rayset file, and the output is a another rayset file. Both rayset files have the format described on pages 49 and 50 of the HARPO report (Jones et al., 1986b), except that the hop number now takes up three columns, columns 77-79.

The HARPX program extends the calculations in range by adding complete ray cycles to both odd and even ray loops. The HARPX program does not check the input rayset file to see if it is consistent with a horizontally uniform medium.

If the source (transmitter) and the receiver are at the same height, then two hops in the input rayset file are sufficient for the calculation. If they are not at the same height, the input rayset file must have at least three hops (three crossings of the ray with the receiver height). Three hops in the input rayset file are always sufficient for a correct calculation.

3. DISTRIBUTION DISK

The following are descriptions of the files on the distribution disk included with this report:

- README--A description of the HARPX program and the files.
- README.WS5--The Wordstar 5.5 master version of README.
- HARPX.FOR--The source program for HARPX (listed in Appendix A).
- HARPX.WS5--The Wordstar 5.5 master version of HARPX.FOR.
- PUNCHX.SAM--Input data file for the sample case for HARPX (shown in Appendix B). It can also be used to compare HARPX with HARPO calculations (compare with file PUNCHOUT.SAM).
- PUNCHOUT.SAM--Output data file from HARPX for the sample case (shown in Appendix C).
- DINPX.SAM--The input data file to HARPO to generate PUNCHX.SAM (shown in Appendix D).
- HARPX.EXE--Executable program HARPX.

- HARPXINP.SAM--Keyboard input for the sample case.

- PUNAM--An output file from HARPX, which is the model identification header from columns 81 through 102 of the first line in each runset of the raysets in file PUNCHX.SAM. (The raysets in file PUNCHX.SAM begin after the line that contains SOFT EOF; in the sample case, each runset begins with WH3 as the first three characters in a line.) The file PUNAM is used as input for the rayset processing program EIGEN (Weickmann et al., 1989). (See line 17, page 14, in Appendix A.).

Updates to HARPX will be available for downloading from an anonymous FTP (file transfer protocol) server. The latest version of HARPX will be in the directory **pub/raytracing/harpx** of the account **anonymous** at the internet address

pooh.wpl.erl.gov (= 140.172.32.11).

Here are the directions for downloading from the anonymcus FTP server:

If you are connected to Internet (NSFNET, ARPANET, MILNET, etc.) you can download HARPX (documentation and source code) at no charge from an anonymous file transfer protocol (FTP) server at the Wave Propagation Laboratory. The procedures are presented below. If you have any questions regarding the connection or procedure, consult your local system administrator or network expert.

1. Log on to a host at your site that is connected to Internet and is running software supporting the FTP command.

2. Invoke FTP by entering the Internet address of the server:

   ftp pooh.wpl.erl.gov

   or

   ftp 140.172.32.11

3. Log on using **anonymous** for the name.

4. Enter your local login name (e.g., smith@node.her.thr.edu) for the password.

5. Enter **cd pub** to select the pub directory.

6. Enter **get README** to transfer the instructions file (ASCII) to your local host. (Consider going directly to instruction 12 after doing this if this is your first time using this FTP account).

7. Enter **cd raytracing/harpx** to select the **pub/raytracing/harpx** subdirectory.

8. Enter **ls** (lower case LS) to list the files in the subdirectory.

9. Enter **get readme.hpx** to get information about HARPX updates. (Consider going directly to instruction 12 after doing this the first time through.)

10. Enter **get <filename>** where <filename> is one of the filenames found with the **ls** command.

11. Repeat instruction 10 to get all of the files needed.

12. Enter **quit** to exit FTP and return to your local host.

13. Review the **README** file for complete instructions concerning the organization of the FTP directories and the files you need to download for each application. If some of the files are compressed, that information will be in the **README** file.

14. Review the **readme.hpx** file to find out the status of HARPX updates (this published version of HARPX in this report is version 1.0).

4. USING HARPX

The program HARPX was written in FORTRAN 77 to run on a microcomputer in an MS DOS environment, but it should run on a variety of computers with minor changes. In the MS DOS environment, the executable file HARPX.EXE on the distribution can probably be run as is.

Otherwise, the file HARPX.FOR can be compiled to produce an executable file. HARPX.FOR is designed to be compiled using Microsoft FORTRAN, but can probably be compiled on other compilers with minor changes.

To run HARPX, simply type

HARPX

and give the following information it requests:

1. Name of the input rayset data file [default = PUNCH].

2. Name of the output rayset data file [default = PUNCHOUT].

3. Whether you want raysets at surface reflections [default = yes].

4. First hop number wanted [default = 1].

5. Last hop number wanted [default = 100].

6. Amount to subtract from the range [default = 0 km].

7. Reference sound speed [default = 1.47865 km/s] (used with the answer to the previous question to determine the amount to subtract from the pulse travel time).

8. Amount to subtract from all the hop numbers [default = 0].

Hitting the carriage return key in answer to any of the eight questions will give the default value. HARPX works also for multiple runsets. The first three of the above eight questions are asked only once. The other five questions are asked for each runset.

Advanced users can avoid having to answer the questions each time by putting the answers in a data file and using redirection of the standard input (as explained in a DOS manual).

Some of the terms are defined in the HARPO or HARPA reports (Jones et al., 1986a,b).

5. SAMPLE CASE

The sample case illustrates how HARPX works and allows the user to make sure HARPX is working correctly. In addition, this particular sample case is designed to show a comparison between HARPX-extended ray paths and HARPO-calculated ray paths.

To make sure HARPX is working correctly, use the following procedure (assuming that HARPX is already compiled, or that the executable file HARPX.EXE on the distribution disk is the appropriate version for the user's computer).

Type the following:

```
HARPX < HARPXINP.SAM
```

This causes input to be redirected from the file HARPXINP.SAM instead of from the keyboard. The contents of HARPXINP.SAM is

```
PUNCHX.SAM
PUNCHOUT
Y
1
14
0
1.5
0
1
14
0
1.5
0
1
14
0
1.5
0
1
14
0
1.5
0
1
14
0
1.5
0
```

This gives the answers to all the questions that HARPX asks that would have required input from the keyboard (see Section 4). This sample case has 5 runsets, and therefore there will be 28 questions = 3 + (5 x 5). (Actually, the file HARPXINP.SAM has five blank lines at the end because HARPX continues to ask questions for the runset after the last one, even though the answers to those questions will not be used. The programming would have been more difficult otherwise.)

During execution, HARPX will read in the file PUNCHX.SAM (on the distribution disk and listed in Appendix B), and output the files PUNCHOUT and PUNAM. If HARPX is operating correctly, then PUNCHOUT should be identical to the file PUNCHOUT.SAM on the distribution disk (and listed in Appendix C). File PUNAM should contain the following five lines of text:

```
2/28/1991    20h56m
2/28/1991    20h56m
2/28/1991    20h56m
2/28/1991    20h56m
2/28/1991    20h56m
```

The sample case allows also the possibility of comparing the HARPX extensions with HARPO calculations. The first two runsets correspond to a source and receiver both 600 meters below sea level. The first runset has two hops calculated by HARPO. Two hops are enough for HARPX to use to extend the runsets, because the source and receiver are at the same depth. The second runset has 10 hops calculated by HARPO. In the sample case, HARPX extends the first two runsets to 14 hops. This allows comparing the first 10 hops in runset #1 of PUNCHOUT.SAM (Appendix C, page

32) with runset #2 in PUNCHX.SAM (Appendix B, page 26) to give a comparison of HARPX with HARPO calculations. They are nearly identical.

The next three runsets have the receiver at 100 meters below sea level and the source at 600 meters below sea level. Because the source and receiver are at different depths, HARPX needs at least three hops calculated by HARPO to make a correct extension. The three runsets have 3, 10, and 14 hops calculated by HARPO in PUNCHX.SAM, which is sufficient for HARPX to make an accurate extension (to 14 hops in the sample case). The last three runsets of PUNCHOUT.SAM (Appendix C, page 36) can be compared with the last two runsets of PUNCHX.SAM (Appendix B, page 28) to give a comparison of HARPX with HARPO calculations. They are nearly identical.

6. HOW HARPX WORKS

The HARPX program extends the calculations in range by adding complete ray cycles to both odd and even ray loops. The HARPX program does not check the input rayset file to see if it is consistent with a horizontally uniform medium.

If the source (transmitter) and the receiver are at the same height, then two hops in the input rayset file are sufficient for the calculation. If they are not at the same height, the input rayset file must have at least three hops (three crossings of the ray with the receiver height). Three hops in the input rayset file are always sufficient for a correct calculation.

7. REFERENCES

Jones, R. M., J. P. Riley, and T. M. Georges (1986a): HARPA--A versatile three-dimensional Hamiltonian ray-tracing program for acoustic waves in the atmosphere above irregular terrain, NOAA report, Environmental Research Laboratories, Boulder, CO, 410 pp.

Jones, R. M., J. P. Riley, and T. M. Georges (1986b): HARPO--A versatile three-dimensional Hamiltonian ray-tracing program for acoustic waves in an ocean with irregular bottom, NOAA report, Environmental Research Laboratories, Boulder, CO, 455 pp.

Weickmann, A. M., J. P. Riley, T. M. Georges, and R. M. Jones (1989): EIGEN--A program to compute eigenrays from HARPA/HARPO raysets, NOAA Tech. Memo. ERL WPL-160, Environmental Research Laboratories, Boulder, CO, 91 pp.

Appendix A: HARPX Program Listing

```
C.HE PROGRAM HARPX, 8 March 1991, 11:30
                              PROGRAM HARPX
C
C     Program to extend HARPO or HARPA raypaths in horizontally uniform media.
C
C     The HARPX program extends HARPO or HARPA raypath calculations that have
C been made for two or three ray loops (hops) in a horizontally uniform medium
C to more loops and correspondingly longer ranges.  The input is a HARPO or
C HARPA rayset file, and the output is a another rayset file.  Both rayset
C files have the format described on pages 49 and 50 of the HARPO report*
C (except that the hop number now takes up three columns, columns 77-79).
C
C    The HARPX program extends the calculations in range by adding complete
C ray cycles to both odd and even ray loops.  The HARPX program does not
C check the input rayset file to see if it is consistent with a horizontally
C uniform medium.
C
C    If the source (transmitter) and the receiver are at the same height, then
C two hops in the input rayset file are sufficient for the calculation.  If
C they are not at the same height, the input rayset file must have at least
C three hops (three crossings of the ray with the receiver height).  Three
C hops in the input rayset file are always sufficient for an accurate
C calculation.  The HARPX program does not always order the different kinds
C (receiver, surface-reflection, or ground-reflection) of raysets correctly in
C the output rayset file.
C
C    Description of the files on the distribution disk.
C
C README - A description of the HARPX program and the files (this file)
C
C README.WS5 - A Wordstar 5.5 version of README
C
C HARPX.FOR - The source program for HARPX
C
C HARPX.WS5 - A Wordstar 5.5 version of HARPX.FOR
C
C PUNCHX.SAM - Input data file for the sample case for HARPX - can also be
C   used to compare HARPX with HARPO calculations (compare with file
C   PUNCHOUT.SAM)
C
C PUNCHOUT.SAM - Output data file from HARPX for the sample case
C
C DINPX.SAM - The input data file to HARPO to generate PUNCHX.SAM
C
C HARPX.EXE - Executable program HARPX
C
C HARPXINP.SAM - Keyboard input for the sample case
C
C PUNAM - (Output file from HARPX) Model identification header from PUNCHX.SAM
C
C
C *Jones, R. M., J. P. Riley, and T. M. Georges (1986), HARPO -- A versatile
C    three-dimensional Hamiltonian ray-tracing program for acoustic waves in
C    an ocean with irregular bottom, NOAA Report, Environmental Research
C    Laboratories, Boulder, CO, 455 pp.
C
      IMPLICIT INTEGER*4 (A-Z)
      PARAMETER (NRSETS=3)
      PARAMETER (NGSETS=2,NSSETS=2)
      PARAMETER (NSUMS=5,NSTRINGS=3)
```

```
      PARAMETER (RLENGTH=NRSETS*NSTRINGS)
      PARAMETER (GLENGTH=NGSETS*NSTRINGS)
      PARAMETER (SLENGTH=NSSETS*NSTRINGS)
      REAL*4 CREF, INREAL4
      REAL*8 INREAL8
      CHARACTER*18 RSTRING(NSTRINGS,NRSETS)
      INTEGER*4 RSUM(NSUMS,NRSETS),RLHOP(NRSETS)
      CHARACTER*18 GSTRING(NSTRINGS,NGSETS)
      INTEGER*4 GSUM(NSUMS,NGSETS),GLHOP(NGSETS)
      CHARACTER*18 SSTRING(NSTRINGS,NSSETS)
      INTEGER*4 SSUM(NSUMS,NSSETS),SLHOP(NSSETS)
      INTEGER*4 CYCLE(NSUMS), RUNSET
      LOGICAL MTYPE,GTYPE,STYPE
      CHARACTER*80 INSTRING80,FILE1,FILE2
      CHARACTER PUNAM*22
      CHARACTER SOFTEST*20,RESTLINE*60
      CHARACTER LINE*80, TLINE*76, TYPE*1, SURFYES*1, TEMP*3
      CHARACTER LINE79*79
C
      DATA RSTRING /RLENGTH*' '/
      DATA GSTRING /GLENGTH*' '/
      DATA SSTRING /SLENGTH*' '/
      DATA RUNSET /0/
C
      CALL README (25)
C
C Open the input and output files.
C
      FILE1 = INSTRING80( 'What is the name of input rayset file?',
     1 'PUNCH')
      OPEN(UNIT=1,FILE=FILE1,STATUS='OLD')
      FILE2 = INSTRING80( 'What is the name of output rayset file?',
     1 'PUNCHOUT')
      OPEN(UNIT=2,FILE=FILE2,STATUS='UNKNOWN')
      OPEN(UNIT=3,FILE='PUNAM',STATUS='UNKNOWN')
C
      SURFYES = INSTRING80(
     1 'Do you want surface-reflection raysets? (y/n)','Y')
      IF(SURFYES.EQ.'y') SURFYES='Y'
C
Copy DINP file (up to the "soft EOF")
5     IF(EOF(1)) GO TO 40
      READ (1,'(A20,A60)') SOFTEST,RESTLINE
      WRITE (2,'(A20,A60)') SOFTEST,RESTLINE
      IF(SOFTEST.NE.'****SOFT EOF***+++++') GO TO 5
C
C Number of hops (loops) for the output rayset file
6     RUNSET = RUNSET + 1
      WRITE (TEMP,'(I3)') RUNSET
      FIRSTHOP=ININT4('What is the first hop number you want for runset'
     1 //TEMP//'?',1)
      NHOPNEW=ININT4('What is the last hop number you want for runset'
     1 //TEMP//'?',100)
C
C Amount to subtract from range
      DRANGE=10000.0*INREAL8(
     1 'How much do you want to subtract from the range for runset'
     2 //TEMP//'? (km)',0.0D0)
      WRITE(*,'('' Verification: ''\)')
      WRITE(*,*) DRANGE
      CREF=INREAL4(
     1 'What reference sound speed do you want to use for runset'
```

```
     2 //TEMP//'? (km/s)',1.47865)
      WRITE(*,'('' Verification: ''\)')
      WRITE(*,*) CREF
      DTIME=10.0*DRANGE/CREF
      WRITE(*,'('' Verification of DTIME: ''\)')
      WRITE(*,*) DTIME
C
C Amount to subtract from hop numbers
      DHOP=ININT4(
     1'How much do you want to subtract from the hop numbers for runset'
     2 //TEMP//'?',0)
      WRITE(*,'('' Verification: ''\)')
      WRITE (*,*) DHOP
C
Copy model identification header (up to 20 lines)
      IF(EOF(1)) GO TO 40
      READ (1,'(A80,A22)') LINE,PUNAM
      WRITE (2,'(A80,A22)') LINE,PUNAM
      WRITE (3,'(A)') PUNAM
C
Copy the rest of the model identification header (up to 19 lines)
      DO 10 I=1,19
      IF(EOF(1)) GO TO 40
      READ (1,'(A79,A1)') LINE79,TYPE
C
C If it was a transmitter rayset, we have finished with the header.
      IF(TYPE.EQ.'T') GO TO 15
C
C If it was not, copy one line of the model identification header,
      WRITE (2,'(A79,A1)') LINE79,TYPE
C then go back to read the next line.
10    CONTINUE
C
C******* read a transmitter rayset
15    READ (LINE79,'(A76,I3)') TLINE, NHOP
      IF(TYPE.NE.'T') STOP 'TRANSMITTER RAYSET EXPECTED'
      IF(NHOP.LT.2) STOP 'AT LEAST 2 HOPS EXPECTED'
      WRITE (2,'(A76,I3,A1)') TLINE, NHOPNEW, TYPE
C
C initialize
      CALL INITIAL(RSUM,NSUMS,RLHOP,NRSETS,DRANGE,DTIME)
      CALL INITIAL(GSUM,NSUMS,GLHOP,NGSETS,DRANGE,DTIME)
      GLHOP(NGSETS)=-1
      CALL INITIAL(SSUM,NSUMS,SLHOP,NSSETS,DRANGE,DTIME)
      SLHOP(NSSETS)=-1
C
C read raysets
      MTYPE=.FALSE.
      GTYPE=.FALSE.
      STYPE=.FALSE.
C
      DO 16 I= 1, 5*NHOP
      IF(EOF(1)) GO TO 40
      READ (1,'(A79,A1)') LINE79,TYPE
C Possibilities for TYPE:
C 'T' Transmitter (source)
C 'G' bottom reflection (Ground)
C 'M' closest approach to receiver height (Minimum distance)
C 'R' at Receiver height
C 'S' maximum number of Steps
C 'E' Extinction
C 'F' exceeded maximum range (Far)
```

```
C 'U' exceeded maximum height (too far Up)
C 'D' went below minimum height (too far Down)
C 'A' ocean surface reflection (reflection Apogee)
C 'X' bottom absorption (eXtinguished)
C
      NGO=1
      IF(TYPE.EQ.'T'.OR.TYPE.EQ. 'F'.OR.TYPE.EQ.'S'.OR.TYPE.EQ.'E'
     1 .OR.TYPE.EQ.'U'.OR.TYPE.EQ.'D') NGO = 2
      IF(TYPE.EQ.'R'.OR.TYPE.EQ.'M') NGO = 3
      IF(TYPE.EQ.'G') NGO = 4
      IF(TYPE.EQ.'A') NGO = 5
C
      GO TO (17,17,151,152,153) NGO
C
151   CALL INRAYSET(LINE79,RSTRING,NSTRINGS,RSUM,NSUMS,RLHOP,NRSETS)
      RSUM(1,NRSETS)=RSUM(1,NRSETS)-DRANGE
      RSUM(2,NRSETS)=RSUM(2,NRSETS)-DTIME
      RSUM(3,NRSETS)=RSUM(3,NRSETS)-DTIME
      IF (RLHOP(NRSETS).LE.FIRSTHOP) GO TO 154
      GO TO 155
152   GTYPE=.TRUE.
      CALL INRAYSET(LINE79,GSTRING,NSTRINGS,GSUM,NSUMS,GLHOP,NGSETS)
      GSUM(1,NGSETS)=GSUM(1,NGSETS)-DRANGE
      GSUM(2,NGSETS)=GSUM(2,NGSETS)-DTIME
      GSUM(3,NGSETS)=GSUM(3,NGSETS)-DTIME
      IF (GLHOP(NGSETS).LE.FIRSTHOP) GO TO 154
      GO TO 155
153   STYPE=.TRUE.
      CALL INRAYSET(LINE79,SSTRING,NSTRINGS,SSUM,NSUMS,SLHOP,NSSETS)
      SSUM(1,NSSETS)=SSUM(1,NSSETS)-DRANGE
      SSUM(2,NSSETS)=SSUM(2,NSSETS)-DTIME
      SSUM(3,NSSETS)=SSUM(3,NSSETS)-DTIME
      IF (SLHOP(NSSETS).GT.FIRSTHOP) GO TO 155
C
154   CONTINUE
C     WRITE (2,'(A79,A1)') LINE79,TYPE
155   IF(TYPE.EQ.'M') MTYPE=.TRUE.
16    CONTINUE
C
17    CONTINUE
C
C Re-initialize hop numbers to handle the case where only one
C   bottom-reflection or surface-reflection rayset have been read.
      IF(GLHOP(NGSETS-1).EQ.-1) GLHOP(NGSETS-1) = GLHOP(NGSETS) - 2
      IF(SLHOP(NSSETS-1).EQ.-1) SLHOP(NSSETS-1) = SLHOP(NSSETS) - 2
C
C Calculate the ray cycle length.
      DO 18 I=1,NSUMS
      CYCLE (I) = RSUM (I,NRSETS) - RSUM (I,NRSETS-2)
18    CONTINUE
C
C Output the raysets
C Each time through the DO LOOP does one ray cycle in the sound channel
C     DO 20 I = 2, NHOPNEW - RLHOP(NRSETS) + 1, 2
      DO 20 I = FIRSTHOP -RLHOP(NRSETS) + 1, NHOPNEW -RLHOP(NRSETS)+1, 2
      NEWHOP=RLHOP(NRSETS) + (RLHOP(NRSETS)-RLHOP(NRSETS-1))*I
C output one ground-reflection rayset for each ray cycle
      IF(GTYPE.AND. MOD(NEWHOP-1-GLHOP(NGSETS),2).EQ.0) CALL OUTSET
     1 (GSTRING,NSTRINGS,CYCLE,GSUM,NSUMS,GLHOP,NGSETS,NEWHOP-1,DHOP,
     2 'G')
C output one surface-reflection rayset for each ray cycle
      IF(STYPE.AND.SURFYES.EQ.'Y'.AND.MOD(NEWHOP-1-SLHOP(NSSETS),2)
```

```
     1 .EQ.0) CALL OUTSET
     2 (SSTRING,NSTRINGS,CYCLE,SSUM,NSUMS,SLHOP,NSSETS,NEWHOP-1,DHOP,
     3 'A')
C output a receiver rayset (two for each ray cycle)
      IF(.NOT.MTYPE) CALL OUTRSET
     1 (RSTRING,NSTRINGS,CYCLE,RSUM,NSUMS,RLHOP,NRSETS,NEWHOP-1,DHOP,
     2 'R')
C output one ground-reflection rayset for each ray cycle
      IF(GTYPE.AND. MOD(NEWHOP-GLHOP(NGSETS),2).EQ.0) CALL OUTSET
     1 (GSTRING,NSTRINGS,CYCLE,GSUM,NSUMS,GLHOP,NGSETS,NEWHOP,DHOP,'G')
C output one surface-reflection rayset for each ray cycle
      IF(STYPE.AND.SURFYES.EQ.'Y'.AND. MOD(NEWHOP-SLHOP(NSSETS),2).EQ.0)
     1 CALL OUTSET
     2 (SSTRING,NSTRINGS,CYCLE,SSUM,NSUMS,SLHOP,NSSETS,NEWHOP,DHOP,'A')
C output a receiver rayset (two for each ray cycle)
      IF(.NOT.MTYPE.AND. NEWHOP.LE.NHOPNEW) CALL OUTRSET
     1 (RSTRING,NSTRINGS,CYCLE,RSUM,NSUMS,RLHOP,NRSETS,NEWHOP,DHOP,'R')
C output a pair or closest-approach raysets (two for each ray cycle)
      IF(MTYPE) THEN
         CALL OUTRSET(RSTRING,NSTRINGS,CYCLE,RSUM,NSUMS,RLHOP,
     1   NRSETS,NEWHOP-1,DHOP,'M')
       IF (NEWHOP.LE.NHOPNEW) CALL OUTRSET
     1 (RSTRING,NSTRINGS,CYCLE,RSUM,NSUMS,RLHOP,NRSETS,NEWHOP,DHOP,'M')
      ENDIF
20    CONTINUE
C
      IF (TYPE.EQ.'T') GO TO 15
      WRITE (2,'(A79,A1)') LINE79,TYPE
      GO TO 6
C
40    STOP 'OUT OF RAYSETS'
      END


      SUBROUTINE INITIAL(SUM,NSUMS,LHOP,NSETS,DRANGE,DTIME)
C
C subroutine to initialize the integer arrays 'SUM' and 'LHOP' to zero
C 'SUM' (output) has two indexes
C 'NSUMS' (input) is the number of number of fields in the raysets that
C   accumulate.
C 'LHOP' (output) has one index
C 'NSETS' (input) is the number of raysets we are saving at one time
C 'DRANGE' (input) is the amount to subtract from the range
C 'DTIME' (input) is the amount to subtract from the time
C
      IMPLICIT INTEGER*4 (A-Z)
      INTEGER*4 SUM(NSUMS,NSETS),LHOP(NSETS)
      DO 10 I=1,NSETS
      LHOP(I)=0
      SUM(1,I)=-DRANGE
      SUM(2,I)=-DTIME
      SUM(3,I)=-DTIME
      DO 10 J=4,NSUMS
      SUM(J,I)=0
10    CONTINUE
      RETURN
      END


      SUBROUTINE INRAYSET(LINE79,STRING,NSTRINGS,SUM,NSUMS,LHOP,NSETS)
```

```
C
C subroutine to shift the rayset values 'STRING' and 'SUM' and then
C   to read in a new rayset from 'LINE79'
C 'LINE79' (input) is a character string with the first 79 lines of a
C   receiver rayset
C 'STRING' (input and output) is a character string array containing the
C   parts of the rayset that do not accumulate
C 'SUM' (input and output) is an integer array containing the parts of
C   the rayset that do accumulate.
C 'LHOP' (input and output) is an integer array containing the hop
C   numbers of the last 'NSETS' of raysets.
C 'NSETS' (input) is the number of raysets being kept
C The values of NSTRINGS and NSUMS must be consistent with the READ
C   statement and the corresponding FORMAT.
C
      CHARACTER*79 LINE79
      CHARACTER*18 STRING(NSTRINGS,NSETS)
      INTEGER*4 SUM(NSUMS,NSETS), LHOP(NSETS)
C
      IF(NSTRINGS.NE.3) THEN
         WRITE (*,'(1X,A)')'The value of NSTRINGS in the calling '
         WRITE (*,'(1X,A)')'sequence of SUBROUTINE INRAYSET must have '
         WRITE(*,'(1X,A)')'a value of 3 to be consistent with the READ '
         WRITE(*,'(1X,A)')'and corresponding FORMAT statements there.  '
         WRITE (*,'(1X,A,I5)') 'Its value is now ',NSTRINGS
         STOP 'Bad value for NSTRINGS.'
      ENDIF
C
      IF(NSUMS.NE.5) THEN
         WRITE (*,'(1X,A)')'The value of NSUMS in the calling '
         WRITE (*,'(1X,A)')'sequence of SUBROUTINE INRAYSET must have '
         WRITE(*,'(1X,A)')'a value of 5 to be consistent with the READ '
         WRITE(*,'(1X,A)')'and corresponding FORMAT statements there.  '
         WRITE (*,'(1X,A,I5)') 'Its value is now ',NSUMS
         STOP 'Bad value for NSUMS.'
      ENDIF
C
      DO 10 J=1,NSTRINGS
      STRING(J,NSETS-1)=STRING(J,NSETS)
10    CONTINUE
      DO 20 I=2,NSETS
      LHOP(I-1)=LHOP(I)
      DO 20 J=1,NSUMS
      SUM(J,I-1)=SUM(J,I)
20    CONTINUE
      READ (LINE79,'(A9,I9,A18,2I10,2I6,A8,I3)')
     1  STRING(1,NSETS),SUM(1,NSETS),STRING(2,NSETS),
     1 (SUM(I,NSETS),I=2,NSUMS),STRING(3,NSETS),LHOP(NSETS)
      RETURN
      END


      SUBROUTINE OUTRSET
     1 (STRING,NSTRINGS,CYCLE,SUM,NSUMS,LHOP,NSETS,NEWHOP,DHOP,TYPE)
C
C subroutine to output one receiver or closest-approach rayset
C All arguments are input parameters.
C 'STRING' is a character string array containing the parts of the
C   rayset that do not accumulate
C 'CYCLE' is an integer array containing the cycle length for the parts
C   of the rayset that accumulate.
```

```
C 'SUM' is an integer array containing the parts of the rayset that do
C   accumulate.
C 'LHOP' is an integer array containing the hop numbers of the raysets
C   in the input rayset file
C 'NSETS' is the number of raysets being kept
C 'NEWHOP' is the hop number for the rayset that is to be output here
C 'DHOP' is the number of hops to subtract before output
C 'TYPE' should be equal to 'R' or 'M'
C 'NSTRINGS' is the number of fields in the raysets that do not
C   accumulate.
C 'NSUMS' is the number of number of fields in the raysets that
C   accumulate.
C The values of NSUMS and NSTRINGS must be consistent with the
C WRITE statement and the corresponding FORMAT.
C
      CHARACTER*1 TYPE
      CHARACTER*18 STRING(NSTRINGS,NSETS)
      INTEGER*4 SUM(NSUMS,NSETS), SUMS(5), LHOP(NSETS), CYCLE(NSUMS)
     1 ,DHOP
C
      IF(NSTRINGS.NE.3) THEN
         WRITE (*,'(1X,A)')'The value of NSTRINGS in the calling '
         WRITE (*,'(1X,A)')'sequence of SUBROUTINE OUTRSET must have '
         WRITE(*,'(1X,A)')'a value of 3 to be consistent with the WRITE'
         WRITE (*,'(1X,A)')'and corresponding FORMAT statements there. '
         WRITE (*,'(1X,A,I5)') 'Its value is now ',NSTRINGS
         STOP 'Bad value for NSTRINGS.'
      ENDIF
C
      IF(NSUMS.NE.5) THEN
         WRITE (*,'(1X,A)')'The value of NSUMS in the calling '
         WRITE (*,'(1X,A)')'sequence of SUBROUTINE OUTRSET must have '
         WRITE(*,'(1X,A)')'a value of 5 to be consistent with the WRITE'
         WRITE(*,'(1X,A)')'and corresponding FORMAT statements there.  '
         WRITE (*,'(1X,A,I5)') 'Its value is now ',NSUMS
         STOP 'Bad value for NSUMS.'
      ENDIF
C
C write receiver or closest-approach rayset
C    for odd (relative to LHOP(NSETS)) hop number
      IF(MOD(NEWHOP-LHOP(NSETS),2).NE.0) THEN
         DO 10 J=1,NSUMS
         SUMS(J)=SUM(J,NSETS-1) +
     1   CYCLE(J)*(NEWHOP+1-LHOP(NSETS))/2
C    1    (SUM(J,NSETS)-SUM(J,NSETS-2))*(NEWHOP+1-LHOP(NSETS))/2
10       CONTINUE
         WRITE (2,'(A9,I9,A18,2I10,2I6,A8,I3,A1)')
     1  STRING(1,NSETS-1),SUMS(1),STRING(2,NSETS-1),(SUMS(J),J=2,NSUMS),
     2   STRING(3,NSETS-1),NEWHOP-DHOP,TYPE
C        write receiver or closest-approach rayset
C        for even (relative to LHOP(NSETS)) hop number
      ELSE
         DO 20 J=1,NSUMS
         SUMS(J)=SUM(J,NSETS) +
     1   CYCLE(J)*(NEWHOP-LHOP(NSETS))/2
20       CONTINUE
         WRITE (2,'(A9,I9,A18,2I10,2I6,A8,I3,A1)')
     1   STRING(1,NSETS),SUMS(1),STRING(2,NSETS),(SUMS(J),J=2,NSUMS),
     2   STRING(3,NSETS),NEWHOP-DHOP,TYPE
      ENDIF
      RETURN
      END
```

```
      SUBROUTINE OUTSET
     1 (STRING,NSTRINGS,CYCLE,SUM,NSUMS,LHOP,NSETS,NEWHOP,DHOP,TYPE)
C
C subroutine to output one ground-reflection or surface-reflection
C   rayset
C All arguments are input parameters.
C 'STRING' is a character string array containing the parts of the
C   rayset that do not accumulate.
C 'CYCLE' is an integer array containing the cycle length for the parts
C   of the rayset that accumulate.
C 'SUM' is an integer array containing the parts of the rayset that do
C   accumulate.
C 'LHOP' is an integer array containing the hop numbers of the raysets
C   in the input rayset file
C 'NSETS' is the number of raysets being kept
C 'NEWHOP' is the hop number for the rayset that is to be output here
C 'DHOP' is the number of hops to subtract before output
C 'TYPE' should be equal to 'G' for ground-reflection raysets
C 'TYPE' should be equal to 'A' for surface-reflection raysets
C 'NSTRINGS' is the number of fields in the raysets that do not
C   accumulate.
C 'NSUMS' is the number of number of fields in the raysets that
C   accumulate.
C The values of NSTRINGS and NSUMS must be consistent with the
C   WRITE statement and the corresponding FORMAT.
C
      CHARACTER*1 TYPE
      CHARACTER*18 STRING(NSTRINGS,NSETS)
      INTEGER*4 SUM(NSUMS,NSETS), SUMS(5), LHOP(NSETS), CYCLE(NSUMS)
     1 ,DHOP
C
      IF(NSTRINGS.NE.3) THEN
         WRITE (*,'(1X,A)')'The value of NSTRINGS in the calling '
         WRITE (*,'(1X,A)')'sequence of SUBROUTINE OUTSET must have '
         WRITE(*,'(1X,A)')'a value of 3 to be consistent with the WRITE'
         WRITE(*,'(1X,A)')'and corresponding FORMAT statements there.  '
         WRITE (*,'(1X,A,I5)') 'Its value is now ',NSTRINGS
         STOP 'Bad value for NSTRINGS.'
      ENDIF
C
      IF(NSUMS.NE.5) THEN
         WRITE (*,'(1X,A)')'The value of NSUMS in the calling '
         WRITE (*,'(1X,A)')'sequence of SUBROUTINE OUTSET must have '
         WRITE(*,'(1X,A)')'a value of 5 to be consistent with the WRITE'
         WRITE (*,'(1X,A)')'and corresponding FORMAT statements there. '
         WRITE (*,'(1X,A,I5)') 'Its value is now ',NSUMS
         STOP 'Bad value for NSUMS.'
      ENDIF
C
C write one ground-reflection or surface-reflection rayset
      DO 20 J=1,NSUMS
      SUMS(J)=SUM(J,NSETS) + (NEWHOP-LHOP(NSETS)) *
     1 CYCLE(J)/(LHOP(NSETS)-LHOP(NSETS-1))
      IF (SUMS(J) .LT. 0) RETURN
20    CONTINUE
      WRITE (2,'(A9,I9,A18,2I10,2I6,A8,I3,A1)')
     1 STRING(1,NSETS),SUMS(1),STRING(2,NSETS),(SUMS(J),J=2,NSUMS),
     2 STRING(3,NSETS),NEWHOP-DHOP,TYPE
      RETURN
      END
```

```
      CHARACTER*80 FUNCTION INSTRING80(MESSAGE,DEFAULT)
C
C
C function to read in a character string from the terminal,
C   but to return the default value if only a carriage return is read
C "MESSAGE" is what tells the user what input is wanted -
C "DEFAULT" is the default value of the string
C
      CHARACTER*(*) MESSAGE, DEFAULT
      CHARACTER*80 LINE, BLANKS
      DATA BLANKS /' '/
      INSTRING80=DEFAULT
      WRITE (*,'(1X,A,A,A,A\)') MESSAGE,' [',DEFAULT,']'
      READ (*,'(A)') LINE
      IF(LINE.NE.BLANKS) INSTRING80=LINE
      RETURN
      END


      INTEGER*4 FUNCTION ININT4(MESSAGE,DEFAULT)
C
C function to read in an integer value from the terminal, but return the
C   default value if only a carrage return is typed by the user
C "MESSAGE" tells the user what kind of input is wanted
C "DEFAULT" is the default value
      CHARACTER*(*) MESSAGE
      INTEGER*4 DEFAULT
C     INTEGER*4 FIRST,LAST
      CHARACTER*80 LINE, BLANKS, TEMP, TRIM
      DATA BLANKS /' '/
      ININT4=DEFAULT
      WRITE (LINE,'(I11)') DEFAULT
C Trim off leading and trailing blanks
C     CALL WHERE_NONBLANK(LINE,FIRST,LAST)
      TEMP=TRIM(LINE)
C     WRITE (*,'(1X,A,A,A,A\)') MESSAGE,' [',LINE(FIRST:LAST),']'
      WRITE (*,'(1X,A,A,A,A\)') MESSAGE,' [',TEMP(:LEN_TRIM(TEMP)),']'
      READ (*,'(A)') LINE
      IF(LINE.NE.BLANKS) READ(LINE,'(I11)') ININT4
      WRITE(*,'('' Verification: ''\)')
      WRITE(*,*) DEFAULT,ININT4
      RETURN
      END


      REAL*4 FUNCTION INREAL4(MESSAGE,DEFAULT)
C
C function to read in a real value from the terminal, but return the
C   default value if only a carrage return is typed by the user
C "MESSAGE" tells the user what kind of input is wanted
C "DEFAULT" is the default value
      CHARACTER*(*) MESSAGE
      REAL*4 DEFAULT
C     INTEGER*4 FIRST,LAST
      CHARACTER*80 LINE, BLANKS, TEMP, TRIM
      DATA BLANKS /' '/
      INREAL4=DEFAULT
      WRITE (LINE,'(G14.5)') DEFAULT
C Trim off leading and trailing blanks
C     CALL WHERE_NONBLANK(LINE,FIRST,LAST)
      TEMP=TRIM(LINE)
C     WRITE (*,'(1X,A,A,A,A\)') MESSAGE,' [',LINE(FIRST:LAST),']'
```

```
      WRITE (*,'(1X,A,A,A,A\)') MESSAGE,' [',TEMP(:LEN_TRIM(TEMP)),']'
      READ (*,'(A)') LINE
      IF(LINE.NE.BLANKS) READ(LINE,'(G10.4)') INREAL4
      WRITE(*,'('' Verification: ''\)')
      WRITE(*,*) DEFAULT,INREAL4
      RETURN
      END


      REAL*8 FUNCTION INREAL8(MESSAGE,DEFAULT)
C
C function to read in a real value from the terminal, but return the
C   default value if only a carrage return is typed by the user
C "MESSAGE" tells the user what kind of input is wanted
C "DEFAULT" is the default value
      CHARACTER*(*) MESSAGE
      REAL*8 DEFAULT
C     INTEGER*4 FIRST,LAST
      CHARACTER*80 LINE, BLANKS, TEMP, TRIM
      DATA BLANKS /' '/
      INREAL8=DEFAULT
      WRITE (LINE,'(G14.5)') DEFAULT
C Trim off leading and trailing blanks
C     CALL WHERE_NONBLANK(LINE,FIRST,LAST)
      TEMP=TRIM(LINE)
C     WRITE (*,'(1X,A,A,A,A\)') MESSAGE,' [',LINE(FIRST:LAST),']'
      WRITE (*,'(1X,A,A,A,A\)') MESSAGE,' [',TEMP(:LEN_TRIM(TEMP)),']'
      READ (*,'(A)') LINE
      IF(LINE.NE.BLANKS) READ(LINE,'(G10.4)') INREAL8
      WRITE(*,'('' Verification: ''\)')
      WRITE(*,*) DEFAULT,INREAL8
      RETURN
      END


      SUBROUTINE WHERE_NONBLANK(STRING,FIRST,LAST)
C Subroutine to help trim a string of leading and trailing blanks
C STRING is the given string (input)
C FIRST is the number of the first non-blank character (output)
C LAST is the number of the last non-blank character (output)
      CHARACTER *(*) STRING
      INTEGER*4 FIRST, LAST
      LAST=LEN_TRIM(STRING)
      DO 10 I=1,LEN(STRING)
      FIRST=I
      IF(STRING(FIRST:FIRST).NE.' ') RETURN
10    CONTINUE
      RETURN
      END


      CHARACTER*80 FUNCTION TRIM(STRING)
C Character function to trim off leading blanks of a character string,
C   'STRING'(input)
      CHARACTER *(*) STRING
      INTEGER*4 FIRST,LAST
      CALL WHERE_NONBLANK(STRING,FIRST,LAST)
      TRIM=STRING(FIRST:LAST)
      RETURN
      END
```

```
      SUBROUTINE README (N)
C
C Subroutine to print to the console the first N lines of file
C    HARPX.FOR
C N is an input parameter.
C
      CHARACTER*78 LINE78
      OPEN(UNIT=10,FILE='HARPX.FOR',STATUS='OLD')
      DO 10 I=1,N
      READ (10,'(2X,A78)') LINE78
      WRITE (*,'(1X,A78)') LINE78
10    CONTINUE
      RETURN
      END
```

Appendix B: File PUNCHX.SAM - Input Data File for the Sample Case for HARPX

All HARPO/HARPA punch files (such as this one) consist of two parts. The first part (before the line that contains "SOFT EOF") is a copy of the input file to HARPO/HARPA for the computer run that produced the punch file. The second part (after the line that contains "SOFT EOF") is the computer-readable output from HARPO/HARPA, and is called the rayset file. In this sample case, the rayset file has 5 runsets. Each line in the rayset file is 80 characters long except the first line in each runset, which contains 102 characters. In this Appendix, those 5 long lines are wrapped so that they print as two lines each. The final 22 characters in those long lines give the date and time when HARPO or HARPA was run to produce the punch file.

```
JONES     RB3    X6464

WH3-1   SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990

  1     6371.3868          EARTH RADIUS TO MSL, KM (6370.)
  3       -.6              TRANSMITTER HEIGHT ABOVE MSL (T=ABOVE BOTTOM), KM
  4        0.      AN KM   N. TRANSMITTER LATITUDE, KM
  5        0.      AN KM   E. TRANSMITTER LONGITUDE, KM
  7      400.      FQ HZ   INITIAL FREQUENCY, HZ
 11       90.      AN DG   INITIAL AZIMUTH ANGLE, DEG
 15        9.75    AN DG   INITIAL ELEVATION ANGLE, DEG
 16       15.75    AN DG   FINAL   ELEVATION ANGLE, DEG
 17        2.0     AN DG   STEP IN ELEVATION ANGLE, DEG
 19        0.              STOP RAYS THAT STRIKE BOTTOM (1=YES; 0=NO)
 20       -.6              RECEIVER HEIGHT ABOVE MSL, KM
 22        2.              MAXIMUM NUMBER OF HOPS (1.)
 23    99000.              MAXIMUM NUMBER OF STEPS PER HOP (1000.)
 26        5.              MAXIMUM RAY HEIGHT ABOVE MSL, KM
 27       -5.              MINIMUM RAY HEIGHT ABOVE MSL, KM
 28     3000.              MAXIMUM RANGE AT MSL, KM
 29        0.              DO: EIGRAY/RNG-TIM/RNG-ELV/NEW-PROJ/RAYTRC/CONT/PROF
 33       20.              MAXIMUM ABSORPTION, DB (999.999)
 42        1.0E-09         MAXIMUM SINGLE-STEP INTEGRATION ERROR (1.0E-4)
 44         .01            INITIAL INTEGRATION STEP SIZE, KM (1.0)
 57        2.              PHASE PATH  (0=NO; 1=INTEGRATE; 2=INTEGRATE/PRINT)
 58        0.              ABSORPTION  (0=NO; 1=INTEGRATE; 2=INTEGRATE/PRINT)
 60        0.              PATH LENGTH (0=NO; 1=INTEGRATE; 2=INTEGRATE/PRINT)
 71      100.              NUMBER OF INTEGRATION STEPS PER PRINT [1.E9]
 72        1.              OUTPUT RAYSETS (1=YES; 0=NO)
 73        0.              DIAGNOSTIC PRINTOUT (1=YES; 0=NO)
 74        0.              PRINT EVERY W(71) RAY STEPS (0=YES; 1=N0)
 76        0.              BINARY RAY OUTPUT (1=YES; 0=NO)
 77       76.              LINES PER PAGE OF PRINTOUT = 76. FOR HPLJ (57.)
 81        4.              RAYPLOT PROJECTION PLANE (4 = VERT. RECTANGULAR)
 82       30.               PLOT-ORDINATE EXPANSION FACTOR [1.]
 83        0.      AN KM    N. LATITUDE OF LEFT PLOT EDGE, KM
 84        0.      AN KM    E. LONGITUDE OF LEFT PLOT EDGE, KM
 85        0.      AN KM    N. LATITUDE OF RIGHT PLOT EDGE, KM
 86      100.      AN KM    E. LONGITUDE OF RIGHT PLOT EDGE, KM
 87       10.      AN KM    DISTANCE BETWEEN RANGE TICKS, KM
 88       -4.               HEIGHT ABOVE MSL OF BOTTOM OF GRAPH, KM
 89        0.               HEIGHT ABOVE MSL OF TOP OF GRAPH, KM
 96        1.               DISTANCE BETWEEN DEPTH TICKS, KM
150        7.              CTANH SOUND SPEED MODEL CHECK NUMBER
152      100.               CTANH BACKGROUND SOUND SPEED DATA SET ID
 -3                        DATA SUBSET FOR BACKGROUND SOUND-SPEED MODEL
  A  profile from Woods Hole, 1 m rounding, mod3 May 5,1990, 1, CVF
```

```
 3       999.0
  LN   M          LN  M          LN  M
      -0.00    1520.84           0.0
    -10.00    1520.66          -1.0
    -20.00    1520.28          -1.0
    -30.00    1519.33          -1.0
    -50.00    1512.44          -1.0
    -75.00    1505.78          -1.0
   -100.00    1503.17          -1.0
   -125.00    1501.06          -1.0
   -150.00    1498.31          -1.0
   -200.00    1491.90          -1.0
   -250.00    1489.08          -1.0
   -300.00    1486.76          -1.0
   -400.00    1482.14          -1.0
   -500.00    1479.35          -1.0
   -600.00    1478.51          -1.0
   -700.00    1478.65          -1.0
   -800.00    1479.04          -1.0
   -900.00    1479.64          -1.0
  -1000.00    1480.27          -1.0
  -1100.00    1481.05          -1.0
  -1200.00    1481.89          -1.0
  -1300.00    1482.82          -1.0
  -1400.00    1483.74          -1.0
  -1500.00    1484.66          -1.0
  -1750.00    1487.46          -1.0
  -2000.00    1490.59          -1.0
  -2500.00    1497.99          -1.0
  -3000.00    1506.03          -1.0
  -3500.00    1514.42          -1.0
  -4000.00    1523.21          -1.0
  -4500.00    1532.23          -1.0
  -5000.00    1541.43           0.0
  999.0
   0        RETURN TO W-ARRAY DATA SET
 175          0.             NPSPEED SOUND SPEED PERTURBATION MODEL NUMBER
 177          0.             NPSPEED PERTURBATION SOUND SPEED DATA SET ID
  -4                         DATA SUBSET FOR SOUND-SPEED PERTURBATION MODEL
   A  ZERO SOUND-SPEED PERTURBATION
   0        RETURN TO W-ARRAY DATA SET
 275          1.             RHORIZ RECEIVER MODEL CHECK NUMBER
  -8                         DATA SUBSET FOR RECEIVER-SURFACE MODEL
   A  RECEIVER SURFACE = SPHERE 600 M BELOW MSL
   0        RETURN TO W-ARRAY DATA SET
 300          1.             GHORIZ BOTTOM MODEL CHECK NUMBER
 302         21.             GLORENZ BOTTOM MODEL DATA SET ID
  -9                         DATA SUBSET FOR BACKGROUND BOTTOM MODEL
   A  BOTTOM DEPTH = 4.0 KM BELOW MSL
   0        RETURN TO W-ARRAY DATA SET
 303         -4.              HEIGHT OF BOTTOM ABOVE MSL, KM
 325          0.             NPBOTM MODEL CHECK NUMBER
 -10                         DATA SUBSET FOR BOTTOM PERTURBATION MODEL
   A  NO BOTTOM PERTURBATION
   0        RETURN TO W-ARRAY DATA SET
 350          1.             SHORIZ MODEL CHECK NUMBER
 352          1.              SHORIZ OCEAN SURFACE DATA SET ID
 -11                         DATA SUBSET FOR OCEAN SURFACE MODEL
   A  OCEAN SURFACE = SPHERE AT MSL
   0        RETURN TO W-ARRAY DATA SET
 353          0.              HEIGHT OF OCEAN SURFACE ABOVE MSL, KM
 375          0.             NPSURF MODEL CHECK NUMBER
```

```
-12                       DATA SUBSET FOR OCEAN SURFACE PERTURBATION MODEL
  A  NO OCEAN SURFACE PERTURBATION
  0       RETURN TO W-ARRAY DATA SET
  0                       **********  END OF RUN SET NUMBER 1  *********
WH3-2    SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
 22        10.            MAXIMUM NUMBER OF HOPS (1.)
  0                       **********  END OF RUN SET NUMBER 2  *********
WH3-3    SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
 20       -.1             RECEIVER HEIGHT ABOVE MSL, KM
 22        3.             MAXIMUM NUMBER OF HOPS (1.)
 -8                       DATA SUBSET FOR RECEIVER-SURFACE MODEL
  A  RECEIVER SURFACE = SPHERE 100 M BELOW MSL
  0       RETURN TO W-ARRAY DATA SET
  0                       **********  END OF RUN SET NUMBER 3  *********
WH3-4    SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
 22        10.            MAXIMUM NUMBER OF HOPS (1.)
  0                       **********  END OF RUN SET NUMBER 4  *********
WH3-5    SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
 22        14.            MAXIMUM NUMBER OF HOPS (1.)
  0                       **********  END OF RUN SET NUMBER 5  *********
****SOFT EOF***+++++
WH3-1    SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
2/28/1991     20h56m
              .0               .0    CTANH      100.0 NPSPEED       .0
GHORIZ      21.0 NPBOTM        .0                  .0               .0
RHORIZ        .0 SHORIZ       1.0    NPSURF        .0
  profile from Woods Hole, 1 m rounding, mod3 May 5,1990, 1, CVF
  ZERO SOUND-SPEED PERTURBATION
  BOTTOM DEPTH = 4.0 KM BELOW MSL
WH30     -6000       0      0      -6000 25132741    9000000    975000        0   0   2T
    -6000     81003       0      0 -9750     548541     548541      0      0    0   0   1R
    -6000    485089       0      0  9750    3275838    3275838      0      0    0   0   2R
WH30     -6000       0      0      -6000 25132741    9000000   1175000        0   0   2T
    -6000     72782       0      0-11750     494092     494092      0      0    0   0   1R
    -6000    515801       0      0 11750    3480064    3480064      0      0    0   0   2R
WH30     -6000       0      0      -6000 25132741    9000000   1375000        0   0   2T
        0     34860       0      0 -2491     236917     236917      0      0    0   0   1A
    -6000     69720       0      0-13750     473834     473834      0      0    0   0   1R
    -6000    553445       0      0 13750    3728301    3728301      0      0    0   0   2R
WH30     -6000       0      0      -6000 25132741    9000000   1575000        0   0   2T
        0     25092       0      0 -8144     172963     172963      0      0    0   0   1A
    -6000     50185       0      0-15750     345925     345925      0      0    0   0   1R
   -40000    208345       0      0  7216    1425338    1425338      0      0    0   0   2G
    -6000    366505       0      0 15750    2504750    2504750      0      0    0   0   2R
                                                                                      -
WH3-2    SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
2/28/1991     20h56m
              .0               .0    CTANH      100.0 NPSPEED       .0
GHORIZ      21.0 NPBOTM        .0                  .0               .0
RHORIZ        .0 SHORIZ       1.0    NPSURF        .0
  profile from Woods Hole, 1 m rounding, mod3 May 5,1990, 1, CVF
  ZERO SOUND-SPEED PERTURBATION
  BOTTOM DEPTH = 4.0 KM BELOW MSL
WH30     -6000       0      0      -6000 25132741    9000000    975000        0   0  10T
    -6000     81003       0      0 -9750     548541     548541      0      0    0   0   1R
    -6000    485089       0      0  9750    3275838    3275838      0      0    0   0   2R
    -6000    566092       0      0 -9750    3824378    3824378      0      0    0   0   3R
    -6000    970177       0      0  9750    6551675    6551675      0      0    0   0   4R
    -6000   1051180       0      0 -9750    7100216    7100216      0      0    0   0   5R
    -6000   1455266       0      0  9750    9827513    9827513      0      0    0   0   6R
    -6000   1536269       0      0 -9750   10376053   10376053      0      0    0   0   7R
    -6000   1940354       0      0  9750   13103350   13103350      0      0    0   0   8R
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        -6000  2021357      0       0 -9750  13651891  13651891     0       0   0   0   9R
        -6000  2425443      0       0  9750  16379188  16379188     0       0   0   0  10R
  WH30    -6000      0      0        -6000 25132741   9000000   1175000         0   0  10T
        -6000    72782      0       0-11750    494092    494092     0       0   0   0   1R
        -6000   515801      0       0 11750   3480064   3480064     0       0   0   0   2R
        -6000   588583      0       0-11750   3974156   3974156     0       0   0   0   3R
        -6000  1031603      0       0 11750   6960127   6960127     0       0   0   0   4R
        -6000  1104384      0       0-11750   7454219   7454219     0       0   0   0   5R
        -6000  1547404      0       0 11750  10440191  10440191     0       0   0   0   6R
        -6000  1620186      0       0-11750  10934283  10934283     0       0   0   0   7R
        -6000  2063205      0       0 11750  13920255  13920255     0       0   0   0   8R
        -6000  2135987      0       0-11750  14414347  14414347     0       0   0   0   9R
        -6000  2579006      0       0 11750  17400319  17400319     0       0   0   0  10R
  WH30    -6000      0      0        -6000 25132741   9000000   1375000         0   0  10T
            0    34860      0       0 -2491    236917    236917     0       0   0   0   1A
        -6000    69720      0       0-13750    473834    473834     0       0   0   0   1R
        -6000   553445      0       0 13750   3728301   3728301     0       0   0   0   2R
            0   588305      0       0 -2491   3965218   3965218     0       0   0   0   3A
        -6000   623165      0       0-13750   4202135   4202135     0       0   0   0   3R
        -6000  1106890      0       0 13750   7456601   7456601     0       0   0   0   4R
            0  1141750      0       0 -2491   7693518   7693518     0       0   0   0   5A
        -6000  1176610      0       0-13750   7930435   7930435     0       0   0   0   5R
        -6000  1660335      0       0 13750  11184902  11184902     0       0   0   0   6R
            0  1695195      0       0 -2491  11421819  11421819     0       0   0   0   7A
        -6000  1730055      0       0-13750  11658736  11658736     0       0   0   0   7R
        -6000  2213779      0       0 13750  14913202  14913202     0       0   0   0   8R
            0  2248640      0       0 -2491  15150119  15150119     0       0   0   0   9A
        -6000  2283500      0       0-13750  15387036  15387036     0       0   0   0   9R
        -6000  2767224      0       0 13750  18641503  18641503     0       0   0   0  10R
  WH30    -6000      0      0        -6000 25132741   9000000   1575000         0   0  10T
            0    25092      0       0 -8144    172963    172963     0       0   0   0   1A
        -6000    50185      0       0-15750    345925    345925     0       0   0   0   1R
       -40000   208345      0       0  7216   1425338   1425338     0       0   0   0   2G
        -6000   366505      0       0 15750   2504750   2504750     0       0   0   0   2R
            0   391598      0       0 -8144   2677713   2677713     0       0   0   0   3A
        -6000   416690      0       0-15750   2850676   2850676     0       0   0   0   3R
       -40000   574851      0       0  7216   3930088   3930088     0       0   0   0   4G
        -6000   733011      0       0 15750   5009501   5009501     0       0   0   0   4R
            0   758103      0       0 -8144   5182463   5182463     0       0   0   0   5A
        -6000   783196      0       0-15750   5355426   5355426     0       0   0   0   5R
       -40000   941356      0       0  7216   6434838   6434838     0       0   0   0   6G
        -6000  1099516      0       0 15750   7514251   7514251     0       0   0   0   6R
            0  1124609      0       0 -8144   7687214   7687214     0       0   0   0   7A
        -6000  1149701      0       0-15750   7860176   7860176     0       0   0   0   7R
       -40000  1307862      0       0  7216   8939589   8939589     0       0   0   0   8G
        -6000  1466022      0       0 15750  10019001  10019001     0       0   0   0   8R
            0  1491114      0       0 -8144  10191964  10191964     0       0   0   0   9A
        -6000  1516207      0       0-15750  10364926  10364926     0       0   0   0   9R
       -40000  1674367      0       0  7216  11444339  11444339     0       0   0   0  10G
        -6000  1832527      0       0 15750  12523751  12523751     0       0   0   0  10R

WH3-3   SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
2/28/1991      20h56m
              .0                   .0     CTANH        100.0 NPSPEED         .0
GHORIZ        21.0 NPBOTM          .0                     .0                  .0
RHORIZ          .0 SHORIZ         1.0     NPSURF          .0
   profile from Woods Hole, 1 m rounding, mod3 May 5,1990, 1, CVF
   ZERO SOUND-SPEED PERTURBATION
   BOTTOM DEPTH = 4.0 KM BELOW MSL
WH30    -6000       0        0     -1000 25132741   9000000     975000        0   0   3T
      -1320     40501       0       0      0   274270    274270      0      0   0   0   1M
      -1320     40501       0       0      0   274270    274270      0      0   0   0   2M
```

```
   -1320   525590      0      0     0   3550108    3550108      0       0    0   0  3M
WH30    -6000      0       0      -1000 25132741   9000000   1175000             0   0  3T
   -1000    29150      0      0  5558    198899     198899      0       0    0   0  1R
   -1000    43632      0      0 -5558    295193     295193      0       0    0   0  2R
   -1000   544951      0      0  5558   3678963    3678963      0       0    0   0  3R
WH30    -6000      0       0      -1000 25132741   9000000   1375000             0   0  3T
   -1000    23018      0      0  9080    158440     158440      0       0    0   0  1R
       0    34860      0      0 -2491    236917     236917      0       0    0   0  2A
   -1000    46702      0      0 -9080    315394     315394      0       0    0   0  2R
   -1000   576463      0      0  9080   3886741    3886741      0       0    0   0  3R
WH30    -6000      0       0      -1000 25132741   9000000   1575000             0   0  3T
   -1000    19288      0      0 11921    134039     134039      0       0    0   0  1R
       0    25092      0      0 -8144    172963     172963      0       0    0   0  2A
   -1000    30896      0      0-11921    211886     211886      0       0    0   0  2R
  -40000   208345      0      0  7216   1425338    1425338      0       0    0   0  3G
   -1000   385794      0      0 11921   2638790    2638790      0       0    0   0  3R

WH3-4   SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
2/28/1991     20h56m
              .0             .0     CTANH      100.0 NPSPEED         .0
GHORIZ     21.0 NPBOTM       .0                   .0                 .0
RHORIZ       .0 SHORIZ      1.0     NPSURF        .0
  profile from Woods Hole, 1 m rounding, mod3 May 5,1990, 1, CVF
  ZERO SOUND-SPEED PERTURBATION
  BOTTOM DEPTH = 4.0 KM BELOW MSL
WH30    -6000      0       0      -1000 25132741   9000000    975000             0   0 10T
   -1320    40501      0      0     0    274270     274270      0       0    0   0  1M
   -1320    40501      0      0     0    274270     274270      0       0    0   0  2M
   -1320   525590      0      0     0   3550108    3550108      0       0    0   0  3M
   -1320   525590      0      0     0   3550108    3550108      0       0    0   0  4M
   -1320  1010679      0      0     0   6825946    6825946      0       0    0   0  5M
   -1320  1010679      0      0     0   6825946    6825946      0       0    0   0  6M
   -1320  1495767      0      0     0  10101783   10101783      0       0    0   0  7M
   -1320  1495767      0      0     0  10101783   10101783      0       0    0   0  8M
   -1320  1980856      0      0     0  13377621   13377621      0       0    0   0  9M
   -1320  1980856      0      0     0  13377621   13377621      0       0    0   0 10M
WH30    -6000      0       0      -1000 25132741   9000000   1175000             0   0 10T
   -1000    29150      0      0  5558    198899     198899      0       0    0   0  1R
   -1000    43632      0      0 -5558    295193     295193      0       0    0   0  2R
   -1000   544951      0      0  5558   3678963    3678963      0       0    0   0  3R
   -1000   559433      0      0 -5558   3775256    3775256      0       0    0   0  4R
   -1000  1060753      0      0  5558   7159027    7159027      0       0    0   0  5R
   -1000  1075234      0      0 -5558   7255320    7255320      0       0    0   0  6R
   -1000  1576554      0      0  5558  10639090   10639090      0       0    0   0  7R
   -1000  1591036      0      0 -5558  10735384   10735384      0       0    0   0  8R
   -1000  2092355      0      0  5558  14119154   14119154      0       0    0   0  9R
   -1000  2106837      0      0 -5558  14215447   14215447      0       0    0   0 10R
WH30    -6000      0       0      -1000 25132741   9000000   1375000             0   0 10T
   -1000    23018      0      0  9080    158440     158440      0       0    0   0  1R
       0    34860      0      0 -2491    236917     236917      0       0    0   0  2A
   -1000    46702      0      0 -9080    315394     315394      0       0    0   0  2R
   -1000   576463      0      0  9080   3886741    3886741      0       0    0   0  3R
       0   588305      0      0 -2491   3965218    3965218      0       0    0   0  4A
   -1000   600147      0      0 -9080   4043695    4043695      0       0    0   0  4R
   -1000  1129908      0      0  9080   7615041    7615041      0       0    0   0  5R
       0  1141750      0      0 -2491   7693518    7693518      0       0    0   0  6A
   -1000  1153591      0      0 -9080   7771995    7771995      0       0    0   0  6R
   -1000  1683353      0      0  9080  11343342   11343342      0       0    0   0  7R
       0  1695195      0      0 -2491  11421819   11421819      0       0    0   0  8A
   -1000  1707036      0      0 -9080  11500296   11500296      0       0    0   0  8R
   -1000  2236798      0      0  9080  15071642   15071642      0       0    0   0  9R
       0  2248640      0      0 -2491  15150119   15150119      0       0    0   0 10A
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    -1000  2260481     0     0 -9080  15228596  15228596     0     0    0    0 10R
WH30    -6000      0     0     -1000 25132741   9000000   1575000         0    0 10T
    -1000    19288     0     0 11921    134039    134039     0     0    0    0  1R
        0    25092     0     0 -8144    172963    172963     0     0    0    0  2A
    -1000    30896     0     0-11921    211886    211886     0     0    0    0  2R
   -40000   208345     0     0  7216   1425338   1425338     0     0    0    0  3G
    -1000   385794     0     0 11921   2638790   2638790     0     0    0    0  3R
        0   391598     0     0 -8144   2677713   2677713     0     0    0    0  4A
    -1000   397402     0     0-11921   2716636   2716636     0     0    0    0  4R
   -40000   574851     0     0  7216   3930088   3930088     0     0    0    0  5G
    -1000   752299     0     0 11921   5143540   5143540     0     0    0    0  5R
        0   758103     0     0 -8144   5182463   5182463     0     0    0    0  6A
    -1000   763907     0     0-11921   5221387   5221387     0     0    0    0  6R
   -40000   941356     0     0  7216   6434839   6434839     0     0    0    0  7G
    -1000  1118805     0     0 11921   7648290   7648290     0     0    0    0  7R
        0  1124609     0     0 -8144   7687214   7687214     0     0    0    0  8A
    -1000  1130413     0     0-11921   7726137   7726137     0     0    0    0  8R
   -40000  1307862     0     0  7216   8939589   8939589     0     0    0    0  9G
    -1000  1485310     0     0 11921  10153041  10153041     0     0    0    0  9R
        0  1491114     0     0 -8144  10191964  10191964     0     0    0    0 10A
    -1000  1496918     0     0-11921  10230887  10230887     0     0    0    0 10R

WH3-5    SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
2/28/1991    20h56m
              .0             .0    CTANH      100.0 NPSPEED        .0
GHORIZ      21.0 NPBOTM      .0                  .0                .0
RHORIZ        .0 SHORIZ     1.0    NPSURF        .0
  profile from Woods Hole, 1 m rounding, mod3 May 5,1990, 1, CVF
  ZERO SOUND-SPEED PERTURBATION
  BOTTOM DEPTH = 4.0 KM BELOW MSL
WH30    -6000      0     0     -1000 25132741   9000000    975000         0    0 14T
    -1320    40501     0     0     0    274270    274270     0     0    0    0  1M
    -1320    40501     0     0     0    274270    274270     0     0    0    0  2M
    -1320   525590     0     0     0   3550108   3550108     0     0    0    0  3M
    -1320   525590     0     0     0   3550108   3550108     0     0    0    0  4M
    -1320  1010679     0     0     0   6825946   6825946     0     0    0    0  5M
    -1320  1010679     0     0     0   6825946   6825946     0     0    0    0  6M
    -1320  1495767     0     0     0  10101783  10101783     0     0    0    0  7M
    -1320  1495767     0     0     0  10101783  10101783     0     0    0    0  8M
    -1320  1980856     0     0     0  13377621  13377621     0     0    0    0  9M
    -1320  1980856     0     0     0  13377621  13377621     0     0    0    0 10M
    -1320  2465945     0     0     0  16653458  16653458     0     0    0    0 11M
    -1320  2465945     0     0     0  16653458  16653458     0     0    0    0 12M
    -1320  2951033     0     0     0  19929296  19929296     0     0    0    0 13M
    -1320  2951033     0     0     0  19929296  19929296     0     0    0    0 14M
WH30    -6000      0     0     -1000 25132741   9000000   1175000         0    0 14T
    -1000    29150     0     0  5558    198899    198899     0     0    0    0  1R
    -1000    43632     0     0 -5558    295193    295193     0     0    0    0  2R
    -1000   544951     0     0  5558   3678963   3678963     0     0    0    0  3R
    -1000   559433     0     0 -5558   3775256   3775256     0     0    0    0  4R
    -1000  1060753     0     0  5558   7159027   7159027     0     0    0    0  5R
    -1000  1075234     0     0 -5558   7255320   7255320     0     0    0    0  6R
    -1000  1576554     0     0  5558  10639090  10639090     0     0    0    0  7R
    -1000  1591036     0     0 -5558  10735384  10735384     0     0    0    0  8R
    -1000  2092355     0     0  5558  14119154  14119154     0     0    0    0  9R
    -1000  2106837     0     0 -5558  14215447  14215447     0     0    0    0 10R
    -1000  2608156     0     0  5558  17599218  17599218     0     0    0    0 11R
    -1000  2622638     0     0 -5558  17695511  17695511     0     0    0    0 12R
    -1000  3123958     0     0  5558  21079282  21079282     0     0    0    0 13R
    -1000  3138440     0     0 -5558  21175575  21175575     0     0    0    0 14R
WH30    -6000      0     0     -1000 25132741   9000000   1375000         0    0 14T
    -1000    23018     0     0  9080    158440    158440     0     0    0    0  1R
```

	0	34860	0	0	-2491	236917	236917	0	0	0	0	2A
	-1000	46702	0	0	-9080	315394	315394	0	0	0	0	2R
	-1000	576463	0	0	9080	3886741	3886741	0	0	0	0	3R
	0	588305	0	0	-2491	3965218	3965218	0	0	0	0	4A
	-1000	600147	0	0	-9080	4043695	4043695	0	0	0	0	4R
	-1000	1129908	0	0	9080	7615041	7615041	0	0	0	0	5R
	0	1141750	0	0	-2491	7693518	7693518	0	0	0	0	6A
	-1000	1153591	0	0	-9080	7771995	7771995	0	0	0	0	6R
	-1000	1683353	0	0	9080	11343342	11343342	0	0	0	0	7R
	0	1695195	0	0	-2491	11421819	11421819	0	0	0	0	8A
	-1000	1707036	0	0	-9080	11500296	11500296	0	0	0	0	8R
	-1000	2236798	0	0	9080	15071642	15071642	0	0	0	0	9R
	0	2248640	0	0	-2491	15150119	15150119	0	0	0	0	10A
	-1000	2260481	0	0	-9080	15228596	15228596	0	0	0	0	10R
	-1000	2790243	0	0	9080	18799943	18799943	0	0	0	0	11R
	0	2802084	0	0	-2491	18878420	18878420	0	0	0	0	12A
	-1000	2813926	0	0	-9080	18956897	18956897	0	0	0	0	12R
	-1000	3343688	0	0	9080	22528243	22528243	0	0	0	0	13R
	0	3355529	0	0	-2491	22606720	22606720	0	0	0	0	14A
	-1000	3367371	0	0	-9080	22685197	22685198	0	0	0	0	14R
WH30	-6000	0	0		-1000	25132741	9000000	1575000		0	0	14T
	-1000	19288	0	0	11921	134039	134039	0	0	0	0	1R
	0	25092	0	0	-8144	172963	172963	0	0	0	0	2A
	-1000	30896	0	0	-11921	211886	211886	0	0	0	0	2R
	-40000	208345	0	0	7216	1425338	1425338	0	0	0	0	3G
	-1000	385794	0	0	11921	2638790	2638790	0	0	0	0	3R
	0	391598	0	0	-8144	2677713	2677713	0	0	0	0	4A
	-1000	397402	0	0	-11921	2716636	2716636	0	0	0	0	4R
	-40000	574851	0	0	7216	3930088	3930088	0	0	0	0	5G
	-1000	752299	0	0	11921	5143540	5143540	0	0	0	0	5R
	0	758103	0	0	-8144	5182463	5182463	0	0	0	0	6A
	-1000	763907	0	0	-11921	5221387	5221387	0	0	0	0	6R
	-40000	941356	0	0	7216	6434839	6434839	0	0	0	0	7G
	-1000	1118805	0	0	11921	7648290	7648290	0	0	0	0	7R
	0	1124609	0	0	-8144	7687214	7687214	0	0	0	0	8A
	-1000	1130413	0	0	-11921	7726137	7726137	0	0	0	0	8R
	-40000	1307862	0	0	7216	8939589	8939589	0	0	0	0	9G
	-1000	1485310	0	0	11921	10153041	10153041	0	0	0	0	9R
	0	1491114	0	0	-8144	10191964	10191964	0	0	0	0	10A
	-1000	1496918	0	0	-11921	10230887	10230887	0	0	0	0	10R
	-40000	1674367	0	0	7216	11444339	11444339	0	0	0	0	11G
	-1000	1851816	0	0	11921	12657791	12657791	0	0	0	0	11R
	0	1857620	0	0	-8144	12696714	12696714	0	0	0	0	12A
	-1000	1863424	0	0	-11921	12735638	12735638	0	0	0	0	12R
	-40000	2040873	0	0	7216	13949089	13949089	0	0	0	0	13G
	-1000	2218321	0	0	11921	15162541	15162541	0	0	0	0	13R
	0	2224125	0	0	-8144	15201465	15201465	0	0	0	0	14A
	-1000	2229929	0	0	-11921	15240388	15240388	0	0	0	0	14R

Appendix C: File PUNCHOUT.SAM - Output Data File from HARPX for the Sample Case

All HARPO/HARPA punch files (such as this one) consist of two parts. The first part (before the line that contains "SOFT EOF") is a copy of the input file to HARPO/HARPA for the computer run that produced the punch file. The second part (after the line that contains "SOFT EOF") is the computer-readable output from HARPO/HARPA, and is called the rayset file. In this sample case, the rayset file has 5 runsets. Each line in the rayset file is 80 characters long except the first line in each runset, which contains 102 characters. In this Appendix, those 5 long lines are wrapped so that they print as two lines each. The final 22 characters in those long lines give the date and time when HARPO or HARPA was run to produce the punch file. The punch file in this Appendix was produced by HARPX rather than HARPO or HARPA, but there is nothing in the format of the file that would indicate whether it was produced by HARPO, HARPA, or HARPX.

```
JONES      RB3    X6464

WH3-1    SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990

  1     6371.3868          EARTH RADIUS TO MSL, KM (6370.)
  3        -.6             TRANSMITTER HEIGHT ABOVE MSL (T=ABOVE BOTTOM), KM
  4       0.       AN KM   N. TRANSMITTER LATITUDE, KM
  5       0.       AN KM   E. TRANSMITTER LONGITUDE, KM
  7      400.      FQ HZ   INITIAL FREQUENCY, HZ
 11       90.      AN DG   INITIAL AZIMUTH ANGLE, DEG
 15       9.75     AN DG   INITIAL ELEVATION ANGLE, DEG
 16       15.75    AN DG   FINAL   ELEVATION ANGLE, DEG
 17       2.0      AN DG   STEP IN ELEVATION ANGLE, DEG
 19       0.               STOP RAYS THAT STRIKE BOTTOM (1=YES; 0=NO)
 20      -.6               RECEIVER HEIGHT ABOVE MSL, KM
 22       2.               MAXIMUM NUMBER OF HOPS (1.)
 23    99000.              MAXIMUM NUMBER OF STEPS PER HOP (1000.)
 26       5.               MAXIMUM RAY HEIGHT ABOVE MSL, KM
 27      -5.               MINIMUM RAY HEIGHT ABOVE MSL, KM
 28     3000.              MAXIMUM RANGE AT MSL, KM
 29       0.               DO: EIGRAY/RNG-TIM/RNG-ELV/NEW-PROJ/RAYTRC/CONT/PROF
 33      20.               MAXIMUM ABSORPTION, DB (999.999)
 42      1.0E-09           MAXIMUM SINGLE-STEP INTEGRATION ERROR (1.0E-4)
 44       .01              INITIAL INTEGRATION STEP SIZE, KM (1.0)
 57       2.               PHASE PATH  (0=NO; 1=INTEGRATE; 2=INTEGRATE/PRINT)
 58       0.               ABSORPTION  (0=NO; 1=INTEGRATE; 2=INTEGRATE/PRINT)
 60       0.               PATH LENGTH (0=NO; 1=INTEGRATE; 2=INTEGRATE/PRINT)
 71     100.               NUMBER OF INTEGRATION STEPS PER PRINT [1.E9]
 72       1.               OUTPUT RAYSETS (1=YES; 0=NO)
 73       0.               DIAGNOSTIC PRINTOUT (1=YES; 0=NO)
 74       0.               PRINT EVERY W(71) RAY STEPS (0=YES; 1=N0)
 76       0.               BINARY RAY OUTPUT (1=YES; 0=NO)
 77      76.               LINES PER PAGE OF PRINTOUT = 76. FOR HPLJ (57.)
 81       4.               RAYPLOT PROJECTION PLANE (4 = VERT. RECTANGULAR)
 82      30.               PLOT-ORDINATE EXPANSION FACTOR [1.]
 83       0.      AN KM    N. LATITUDE OF LEFT PLOT EDGE, KM
 84       0.      AN KM    E. LONGITUDE OF LEFT PLOT EDGE, KM
 85       0.      AN KM    N. LATITUDE OF RIGHT PLOT EDGE, KM
 86     100.      AN KM    E. LONGITUDE OF RIGHT PLOT EDGE, KM
 87      10.      AN KM    DISTANCE BETWEEN RANGE TICKS, KM
 88      -4.               HEIGHT ABOVE MSL OF BOTTOM OF GRAPH, KM
 89       0.               HEIGHT ABOVE MSL OF TOP OF GRAPH, KM
 96       1.               DISTANCE BETWEEN DEPTH TICKS, KM
150       7.               CTANH SOUND SPEED MODEL CHECK NUMBER
```

```
152      100.              CTANH BACKGROUND SOUND SPEED DATA SET ID
 -3                        DATA SUBSET FOR BACKGROUND SOUND-SPEED MODEL

 A  profile from Woods Hole, 1 m rounding, mod3 May 5,1990, 1, CVF

 3        999.0
  LN  M          LN  M            LN  M
      -0.00    1520.84          0.0
     -10.00    1520.66         -1.0
     -20.00    1520.28         -1.0
     -30.00    1519.33         -1.0
     -50.00    1512.44         -1.0
     -75.00    1505.78         -1.0
    -100.00    1503.17         -1.0
    -125.00    1501.06         -1.0
    -150.00    1498.31         -1.0
    -200.00    1491.90         -1.0
    -250.00    1489.08         -1.0
    -300.00    1486.76         -1.0
    -400.00    1482.14         -1.0
    -500.00    1479.35         -1.0
    -600.00    1478.51         -1.0
    -700.00    1478.65         -1.0
    -800.00    1479.04         -1.0
    -900.00    1479.64         -1.0
   -1000.00    1480.27         -1.0
   -1100.00    1481.05         -1.0
   -1200.00    1481.89         -1.0
   -1300.00    1482.82         -1.0
   -1400.00    1483.74         -1.0
   -1500.00    1484.66         -1.0
   -1750.00    1487.46         -1.0
   -2000.00    1490.59         -1.0
   -2500.00    1497.99         -1.0
   -3000.00    1506.03         -1.0
   -3500.00    1514.42         -1.0
   -4000.00    1523.21         -1.0
   -4500.00    1532.23         -1.0
   -5000.00    1541.43          0.0
    999.0
 0        RETURN TO W-ARRAY DATA SET
175        0.              NPSPEED SOUND SPEED PERTURBATION MODEL NUMBER
177        0.              NPSPEED PERTURBATION SOUND SPEED DATA SET ID
 -4                        DATA SUBSET FOR SOUND-SPEED PERTURBATION MODEL
 A   ZERO SOUND-SPEED PERTURBATION
 0        RETURN TO W-ARRAY DATA SET
275        1.              RHORIZ RECEIVER MODEL CHECK NUMBER
 -8                        DATA SUBSET FOR RECEIVER-SURFACE MODEL
 A   RECEIVER SURFACE = SPHERE 600 M BELOW MSL
 0        RETURN TO W-ARRAY DATA SET
300        1.              GHORIZ BOTTOM MODEL CHECK NUMBER
302       21.              GLORENZ BOTTOM MODEL DATA SET ID
 -9                        DATA SUBSET FOR BACKGROUND BOTTOM MODEL
 A   BOTTOM DEPTH = 4.0 KM BELOW MSL
 0        RETURN TO W-ARRAY DATA SET
303       -4.                HEIGHT OF BOTTOM ABOVE MSL, KM
325        0.              NPBOTM MODEL CHECK NUMBER
-10                        DATA SUBSET FOR BOTTOM PERTURBATION MODEL
 A   NO BOTTOM PERTURBATION
 0        RETURN TO W-ARRAY DATA SET
350        1.              SHORIZ MODEL CHECK NUMBER
352        1.                SHORIZ OCEAN SURFACE DATA SET ID
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-11                      DATA SUBSET FOR OCEAN SURFACE MODEL
  A  OCEAN SURFACE = SPHERE AT MSL
  0      RETURN TO W-ARRAY DATA SET
353       0.               HEIGHT OF OCEAN SURFACE ABOVE MSL, KM
375       0.             NPSURF MODEL CHECK NUMBER
-12                      DATA SUBSET FOR OCEAN SURFACE PERTURBATION MODEL
  A  NO OCEAN SURFACE PERTURBATION
  0      RETURN TO W-ARRAY DATA SET
  0                      **********  END OF RUN SET NUMBER 1  *********
WH3-2    SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
 22       10.            MAXIMUM NUMBER OF HOPS (1.)
  0                      **********  END OF RUN SET NUMBER 2  *********
WH3-3    SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
 20       -.1            RECEIVER HEIGHT ABOVE MSL, KM
 22        3.            MAXIMUM NUMBER OF HOPS (1.)
 -8                      DATA SUBSET FOR RECEIVER-SURFACE MODEL
  A  RECEIVER SURFACE = SPHERE 100 M BELOW MSL
  0      RETURN TO W-ARRAY DATA SET
  0                      **********  END OF RUN SET NUMBER 3  *********
WH3-4    SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
 22       10.            MAXIMUM NUMBER OF HOPS (1.)
  0                      **********  END OF RUN SET NUMBER 4  *********
WH3-5    SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
 22       14.            MAXIMUM NUMBER OF HOPS (1.)
  0                      **********  END OF RUN SET NUMBER 5  *********
****SOFT EOF***++++++
WH3-1    SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
2/28/1991     20h56m
              .0                  .0    CTANH      100.0 NPSPEED       .0
GHORIZ     21.0 NPBOTM            .0                  .0                   .0
RHORIZ       .0 SHORIZ           1.0    NPSURF        .0
  profile from Woods Hole, 1 m rounding, mod3 May 5,1990, 1, CVF
  ZERO SOUND-SPEED PERTURBATION
  BOTTOM DEPTH = 4.0 KM BELOW MSL
WH30     -6000       0      0    -6000 25132741   9000000    975000         0     0 14T
     -6000    81003      0      0 -9750    548541    548541       0      0     0     0  1R
     -6000   485089      0      0  9750   3275838   3275838       0      0     0     0  2R
     -6000   566092      0      0 -9750   3824379   3824379       0      0     0     0  3R
     -6000   970178      0      0  9750   6551676   6551676       0      0     0     0  4R
     -6000  1051181      0      0 -9750   7100217   7100217       0      0     0     0  5R
     -6000  1455267      0      0  9750   9827514   9827514       0      0     0     0  6R
     -6000  1536270      0      0 -9750  10376055  10376055       0      0     0     0  7R
     -6000  1940356      0      0  9750  13103352  13103352       0      0     0     0  8R
     -6000  2021359      0      0 -9750  13651893  13651893       0      0     0     0  9R
     -6000  2425445      0      0  9750  16379190  16379190       0      0     0     0 10R
     -6000  2506448      0      0 -9750  16927731  16927731       0      0     0     0 11R
     -6000  2910534      0      0  9750  19655028  19655028       0      0     0     0 12R
     -6000  2991537      0      0 -9750  20203569  20203569       0      0     0     0 13R
     -6000  3395623      0      0  9750  22930866  22930866       0      0     0     0 14R
WH30     -6000       0      0    -6000 25132741   9000000   1175000         0     0 14T
     -6000    72782      0      0-11750    494092    494092       0      0     0     0  1R
     -6000   515801      0      0 11750   3480064   3480064       0      0     0     0  2R
     -6000   588583      0      0-11750   3974156   3974156       0      0     0     0  3R
     -6000  1031602      0      0 11750   6960128   6960128       0      0     0     0  4R
     -6000  1104384      0      0-11750   7454220   7454220       0      0     0     0  5R
     -6000  1547403      0      0 11750  10440192  10440192       0      0     0     0  6R
     -6000  1620185      0      0-11750  10934284  10934284       0      0     0     0  7R
     -6000  2063204      0      0 11750  13920256  13920256       0      0     0     0  8R
     -6000  2135986      0      0-11750  14414348  14414348       0      0     0     0  9R
     -6000  2579005      0      0 11750  17400320  17400320       0      0     0     0 10R
     -6000  2651787      0      0-11750  17894412  17894412       0      0     0     0 11R
     -6000  3094806      0      0 11750  20880384  20880384       0      0     0     0 12R
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      -6000  3167588      0      0-11750  21374476  21374476      0      0     0     0 13R
      -6000  3610607      0      0 11750  24360448  24360448      0      0     0     0 14R
 WH30     -6000       0      0      -6000 25132741   9000000   1375000         0     0 14T
          0    34860      0      0 -2491    236917    236917      0      0     0     0  1A
      -6000    69720      0      0-13750    473834    473834      0      0     0     0  1R
      -6000   553445      0      0 13750   3728301   3728301      0      0     0     0  2R
          0   588305      0      0 -2491   3965218   3965218      0      0     0     0  3A
      -6000   623165      0      0-13750   4202135   4202135      0      0     0     0  3R
      -6000  1106890      0      0 13750   7456602   7456602      0      0     0     0  4R
          0  1141750      0      0 -2491   7693519   7693519      0      0     0     0  5A
      -6000  1176610      0      0-13750   7930436   7930436      0      0     0     0  5R
      -6000  1660335      0      0 13750  11184903  11184903      0      0     0     0  6R
          0  1695195      0      0 -2491  11421820  11421820      0      0     0     0  7A
      -6000  1730055      0      0-13750  11658737  11658737      0      0     0     0  7R
      -6000  2213780      0      0 13750  14913204  14913204      0      0     0     0  8R
          0  2248640      0      0 -2491  15150121  15150121      0      0     0     0  9A
      -6000  2283500      0      0-13750  15387038  15387038      0      0     0     0  9R
      -6000  2767225      0      0 13750  18641505  18641505      0      0     0     0 10R
          0  2802085      0      0 -2491  18878422  18878422      0      0     0     0 11A
      -6000  2836945      0      0-13750  19115339  19115339      0      0     0     0 11R
      -6000  3320670      0      0 13750  22369806  22369806      0      0     0     0 12R
          0  3355530      0      0 -2491  22606723  22606723      0      0     0     0 13A
      -6000  3390390      0      0-13750  22843640  22843640      0      0     0     0 13R
      -6000  3874115      0      0 13750  26098107  26098107      0      0     0     0 14R
 WH30     -6000       0      0      -6000 25132741   9000000   1575000         0     0 14T
          0    25092      0      0 -8144    172963    172963      0      0     0     0  1A
      -6000    50185      0      0-15750    345925    345925      0      0     0     0  1R
     -40000   208345      0      0  7216   1425338   1425338      0      0     0     0  2G
      -6000   366505      0      0 15750   2504750   2504750      0      0     0     0  2R
          0   391597      0      0 -8144   2677713   2677713      0      0     0     0  3A
      -6000   416690      0      0-15750   2850675   2850675      0      0     0     0  3R
     -40000   574850      0      0  7216   3930088   3930088      0      0     0     0  4G
      -6000   733010      0      0 15750   5009500   5009500      0      0     0     0  4R
          0   758102      0      0 -8144   5182463   5182463      0      0     0     0  5A
      -6000   783195      0      0-15750   5355425   5355425      0      0     0     0  5R
     -40000   941355      0      0  7216   6434838   6434838      0      0     0     0  6G
      -6000  1099515      0      0 15750   7514250   7514250      0      0     0     0  6R
          0  1124607      0      0 -8144   7687213   7687213      0      0     0     0  7A
      -6000  1149700      0      0-15750   7860175   7860175      0      0     0     0  7R
     -40000  1307860      0      0  7216   8939588   8939588      0      0     0     0  8G
      -6000  1466020      0      0 15750  10019000  10019000      0      0     0     0  8R
          0  1491112      0      0 -8144  10191963  10191963      0      0     0     0  9A
      -6000  1516205      0      0-15750  10364925  10364925      0      0     0     0  9R
     -40000  1674365      0      0  7216  11444338  11444338      0      0     0     0 10G
      -6000  1832525      0      0 15750  12523750  12523750      0      0     0     0 10R
          0  1857617      0      0 -8144  12696713  12696713      0      0     0     0 11A
      -6000  1882710      0      0-15750  12869675  12869675      0      0     0     0 11R
     -40000  2040870      0      0  7216  13949088  13949088      0      0     0     0 12G
      -6000  2199030      0      0 15750  15028500  15028500      0      0     0     0 12R
          0  2224122      0      0 -8144  15201463  15201463      0      0     0     0 13A
      -6000  2249215      0      0-15750  15374425  15374425      0      0     0     0 13R
     -40000  2407375      0      0  7216  16453838  16453838      0      0     0     0 14G
      -6000  2565535      0      0 15750  17533250  17533250      0      0     0     0 14R
                                                                                     -
 WH3-2   SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
 2/28/1991     20h56m
                  .0                .0    CTANH       100.0 NPSPEED         .0
 GHORIZ       21.0 NPBOTM           .0                   .0                   .0
 RHORIZ         .0 SHORIZ          1.0     NPSURF        .0
   profile from Woods Hole, 1 m rounding, mod3 May 5,1990, 1, CVF
   ZERO SOUND-SPEED PERTURBATION
   BOTTOM DEPTH = 4.0 KM BELOW MSL
```

WH30	-6000	0	0		-6000	25132741	9000000	975000		0	0	14T
	-6000	81001	0	0	-9750	548539	548539	0	0	0	0	1R
	-6000	485087	0	0	9750	3275836	3275836	0	0	0	0	2R
	-6000	566090	0	0	-9750	3824377	3824377	0	0	0	0	3R
	-6000	970176	0	0	9750	6551674	6551674	0	0	0	0	4R
	-6000	1051179	0	0	-9750	7100215	7100215	0	0	0	0	5R
	-6000	1455265	0	0	9750	9827512	9827512	0	0	0	0	6R
	-6000	1536268	0	0	-9750	10376053	10376053	0	0	0	0	7R
	-6000	1940354	0	0	9750	13103350	13103350	0	0	0	0	8R
	-6000	2021357	0	0	-9750	13651891	13651891	0	0	0	0	9R
	-6000	2425443	0	0	9750	16379188	16379188	0	0	0	0	10R
	-6000	2506446	0	0	-9750	16927729	16927729	0	0	0	0	11R
	-6000	2910532	0	0	9750	19655026	19655026	0	0	0	0	12R
	-6000	2991535	0	0	-9750	20203567	20203567	0	0	0	0	13R
	-6000	3395621	0	0	9750	22930864	22930864	0	0	0	0	14R
WH30	-6000	0	0		-6000	25132741	9000000	1175000		0	0	14T
	-6000	72783	0	0	-11750	494091	494091	0	0	0	0	1R
	-6000	515802	0	0	11750	3480063	3480063	0	0	0	0	2R
	-6000	588584	0	0	-11750	3974155	3974155	0	0	0	0	3R
	-6000	1031603	0	0	11750	6960127	6960127	0	0	0	0	4R
	-6000	1104385	0	0	-11750	7454219	7454219	0	0	0	0	5R
	-6000	1547404	0	0	11750	10440191	10440191	0	0	0	0	6R
	-6000	1620186	0	0	-11750	10934283	10934283	0	0	0	0	7R
	-6000	2063205	0	0	11750	13920255	13920255	0	0	0	0	8R
	-6000	2135987	0	0	-11750	14414347	14414347	0	0	0	0	9R
	-6000	2579006	0	0	11750	17400319	17400319	0	0	0	0	10R
	-6000	2651788	0	0	-11750	17894411	17894411	0	0	0	0	11R
	-6000	3094807	0	0	11750	20880383	20880383	0	0	0	0	12R
	-6000	3167589	0	0	-11750	21374475	21374475	0	0	0	0	13R
	-6000	3610608	0	0	11750	24360447	24360447	0	0	0	0	14R
WH30	-6000	0	0		-6000	25132741	9000000	1375000		0	0	14T
	0	34860	0	0	-2491	236915	236915	0	0	0	0	1A
	-6000	69720	0	0	-13750	473832	473832	0	0	0	0	1R
	-6000	553444	0	0	13750	3728299	3728299	0	0	0	0	2R
	0	588305	0	0	-2491	3965216	3965216	0	0	0	0	3A
	-6000	623165	0	0	-13750	4202133	4202133	0	0	0	0	3R
	-6000	1106889	0	0	13750	7456600	7456600	0	0	0	0	4R
	0	1141750	0	0	-2491	7693517	7693517	0	0	0	0	5A
	-6000	1176610	0	0	-13750	7930434	7930434	0	0	0	0	5R
	-6000	1660334	0	0	13750	11184901	11184901	0	0	0	0	6R
	0	1695195	0	0	-2491	11421818	11421818	0	0	0	0	7A
	-6000	1730055	0	0	-13750	11658735	11658735	0	0	0	0	7R
	-6000	2213779	0	0	13750	14913202	14913202	0	0	0	0	8R
	0	2248640	0	0	-2491	15150119	15150119	0	0	0	0	9A
	-6000	2283500	0	0	-13750	15387036	15387036	0	0	0	0	9R
	-6000	2767224	0	0	13750	18641503	18641503	0	0	0	0	10R
	0	2802085	0	0	-2491	18878420	18878420	0	0	0	0	11A
	-6000	2836945	0	0	-13750	19115337	19115337	0	0	0	0	11R
	-6000	3320669	0	0	13750	22369804	22369804	0	0	0	0	12R
	0	3355530	0	0	-2491	22606721	22606721	0	0	0	0	13A
	-6000	3390390	0	0	-13750	22843638	22843638	0	0	0	0	13R
	-6000	3874114	0	0	13750	26098105	26098105	0	0	0	0	14R
WH30	-6000	0	0		-6000	25132741	9000000	1575000		0	0	14T
	0	25094	0	0	-8144	172964	172964	0	0	0	0	1A
	-6000	50187	0	0	-15750	345926	345926	0	0	0	0	1R
	-40000	208347	0	0	7216	1425339	1425339	0	0	0	0	2G
	-6000	366507	0	0	15750	2504751	2504751	0	0	0	0	2R
	0	391599	0	0	-8144	2677714	2677714	0	0	0	0	3A
	-6000	416692	0	0	-15750	2850676	2850676	0	0	0	0	3R
	-40000	574852	0	0	7216	3930089	3930089	0	0	0	0	4G
	-6000	733012	0	0	15750	5009501	5009501	0	0	0	0	4R
	0	758104	0	0	-8144	5182464	5182464	0	0	0	0	5A

```
   -6000   783197     0      0-15750    5355426    5355426     0       0     0     0  5R
  -40000   941357     0      0  7216    6434839    6434839     0       0     0     0  6G
   -6000  1099517     0      0 15750    7514251    7514251     0       0     0     0  6R
       0  1124609     0      0 -8144    7687214    7687214     0       0     0     0  7A
   -6000  1149702     0      0-15750    7860176    7860176     0       0     0     0  7R
  -40000  1307862     0      0  7216    8939589    8939589     0       0     0     0  8G
   -6000  1466022     0      0 15750   10019001   10019001     0       0     0     0  8R
       0  1491114     0      0 -8144   10191964   10191964     0       0     0     0  9A
   -6000  1516207     0      0-15750   10364926   10364926     0       0     0     0  9R
  -40000  1674367     0      0  7216   11444339   11444339     0       0     0     0 10G
   -6000  1832527     0      0 15750   12523751   12523751     0       0     0     0 10R
       0  1857619     0      0 -8144   12696714   12696714     0       0     0     0 11A
   -6000  1882712     0      0-15750   12869676   12869676     0       0     0     0 11R
  -40000  2040872     0      0  7216   13949089   13949089     0       0     0     0 12G
   -6000  2199032     0      0 15750   15028501   15028501     0       0     0     0 12R
       0  2224124     0      0 -8144   15201464   15201464     0       0     0     0 13A
   -6000  2249217     0      0-15750   15374426   15374426     0       0     0     0 13R
  -40000  2407377     0      0  7216   16453839   16453839     0       0     0     0 14G
   -6000  2565537     0      0 15750   17533251   17533251     0       0     0     0 14R
                                                                                       -
WH3-3   SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
2/28/1991     20h56m
                 .0                  .0    CTANH       100.0 NPSPEED          .0
GHORIZ      21.0 NPBOTM              .0                   .0                  .0
RHORIZ        .0 SHORIZ             1.0    NPSURF         .0
  profile from Woods Hole, 1 m rounding, mod3 May 5,1990, 1, CVF
  ZERO SOUND-SPEED PERTURBATION
  BOTTOM DEPTH = 4.0 KM BELOW MSL
WH30     -6000      0      0      -1000 25132741   9000000     975000          0     0 14T
    -1320      40501     0      0     0     274270     274270     0       0     0     0  1M
    -1320      40501     0      0     0     274270     274270     0       0     0     0  2M
    -1320     525590     0      0     0    3550108    3550108     0       0     0     0  3M
    -1320     525590     0      0     0    3550108    3550108     0       0     0     0  4M
    -1320    1010679     0      0     0    6825946    6825946     0       0     0     0  5M
    -1320    1010679     0      0     0    6825946    6825946     0       0     0     0  6M
    -1320    1495768     0      0     0   10101784   10101784     0       0     0     0  7M
    -1320    1495768     0      0     0   10101784   10101784     0       0     0     0  8M
    -1320    1980857     0      0     0   13377622   13377622     0       0     0     0  9M
    -1320    1980857     0      0     0   13377622   13377622     0       0     0     0 10M
    -1320    2465946     0      0     0   16653460   16653460     0       0     0     0 11M
    -1320    2465946     0      0     0   16653460   16653460     0       0     0     0 12M
    -1320    2951035     0      0     0   19929298   19929298     0       0     0     0 13M
    -1320    2951035     0      0     0   19929298   19929298     0       0     0     0 14M
WH30     -6000      0      0      -1000 25132741   9000000    1175000          0     0 14T
    -1000      29150     0      0  5558     198899     198899     0       0     0     0  1R
    -1000      43632     0      0 -5558     295193     295193     0       0     0     0  2R
    -1000     544951     0      0  5558    3678963    3678963     0       0     0     0  3R
    -1000     559433     0      0 -5558    3775257    3775257     0       0     0     0  4R
    -1000    1060752     0      0  5558    7159027    7159027     0       0     0     0  5R
    -1000    1075234     0      0 -5558    7255321    7255321     0       0     0     0  6R
    -1000    1576553     0      0  5558   10639091   10639091     0       0     0     0  7R
    -1000    1591035     0      0 -5558   10735385   10735385     0       0     0     0  8R
    -1000    2092354     0      0  5558   14119155   14119155     0       0     0     0  9R
    -1000    2106836     0      0 -5558   14215449   14215449     0       0     0     0 10R
    -1000    2608155     0      0  5558   17599219   17599219     0       0     0     0 11R
    -1000    2622637     0      0 -5558   17695513   17695513     0       0     0     0 12R
    -1000    3123956     0      0  5558   21079283   21079283     0       0     0     0 13R
    -1000    3138438     0      0 -5558   21175577   21175577     0       0     0     0 14R
WH30     -6000      0      0      -1000 25132741   9000000    1375000          0     0 14T
    -1000      23018     0      0  9080     158440     158440     0       0     0     0  1R
        0      34860     0      0 -2491     236917     236917     0       0     0     0  2A
    -1000      46702     0      0 -9080     315394     315394     0       0     0     0  2R
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    -1000    576463       0       0  9080    3886741     3886741       0       0     0     0  3R
        0    588305       0       0 -2491    3965218     3965218       0       0     0     0  4A
    -1000    600147       0       0 -9080    4043695     4043695       0       0     0     0  4R
    -1000   1129908       0       0  9080    7615042     7615042       0       0     0     0  5R
        0   1141750       0       0 -2491    7693519     7693519       0       0     0     0  6A
    -1000   1153592       0       0 -9080    7771996     7771996       0       0     0     0  6R
    -1000   1683353       0       0  9080   11343343    11343343       0       0     0     0  7R
        0   1695195       0       0 -2491   11421820    11421820       0       0     0     0  8A
    -1000   1707037       0       0 -9080   11500297    11500297       0       0     0     0  8R
    -1000   2236798       0       0  9080   15071644    15071644       0       0     0     0  9R
        0   2248640       0       0 -2491   15150121    15150121       0       0     0     0 10A
    -1000   2260482       0       0 -9080   15228598    15228598       0       0     0     0 10R
    -1000   2790243       0       0  9080   18799945    18799945       0       0     0     0 11R
        0   2802085       0       0 -2491   18878422    18878422       0       0     0     0 12A
    -1000   2813927       0       0 -9080   18956899    18956899       0       0     0     0 12R
    -1000   3343688       0       0  9080   22528246    22528246       0       0     0     0 13R
        0   3355530       0       0 -2491   22606723    22606723       0       0     0     0 14A
    -1000   3367372       0       0 -9080   22685200    22685200       0       0     0     0 14R
WH30    -6000       0       0      -1000 25132741     9000000    1575000              0     0 14T
    -1000     19288       0       0 11921     134039      134039       0       0     0     0  1R
        0     25092       0       0 -8144     172963      172963       0       0     0     0  2A
    -1000     30896       0       0-11921     211886      211886       0       0     0     0  2R
   -40000    208345       0       0  7216    1425338     1425338       0       0     0     0  3G
    -1000    385794       0       0 11921    2638790     2638790       0       0     0     0  3R
        0    391598       0       0 -8144    2677714     2677714       0       0     0     0  4A
    -1000    397402       0       0-11921    2716637     2716637       0       0     0     0  4R
   -40000    574851       0       0  7216    3930089     3930089       0       0     0     0  5G
    -1000    752300       0       0 11921    5143541     5143541       0       0     0     0  5R
        0    758104       0       0 -8144    5182465     5182465       0       0     0     0  6A
    -1000    763908       0       0-11921    5221388     5221388       0       0     0     0  6R
   -40000    941357       0       0  7216    6434840     6434840       0       0     0     0  7G
    -1000   1118806       0       0 11921    7648292     7648292       0       0     0     0  7R
        0   1124610       0       0 -8144    7687216     7687216       0       0     0     0  8A
    -1000   1130414       0       0-11921    7726139     7726139       0       0     0     0  8R
   -40000   1307863       0       0  7216    8939591     8939591       0       0     0     0  9G
    -1000   1485312       0       0 11921   10153043    10153043       0       0     0     0  9R
        0   1491116       0       0 -8144   10191967    10191967       0       0     0     0 10A
    -1000   1496920       0       0-11921   10230890    10230890       0       0     0     0 10R
   -40000   1674369       0       0  7216   11444342    11444342       0       0     0     0 11G
    -1000   1851818       0       0 11921   12657794    12657794       0       0     0     0 11R
        0   1857622       0       0 -8144   12696718    12696718       0       0     0     0 12A
    -1000   1863426       0       0-11921   12735641    12735641       0       0     0     0 12R
   -40000   2040875       0       0  7216   13949093    13949093       0       0     0     0 13G
    -1000   2218324       0       0 11921   15162545    15162545       0       0     0     0 13R
        0   2224128       0       0 -8144   15201469    15201469       0       0     0     0 14A
    -1000   2229932       0       0-11921   15240392    15240392       0       0     0     0 14R

WH3-4   SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
2/28/1991     20h56m
               .0               .0    CTANH      100.0 NPSPEED         .0
GHORIZ      21.0 NPBOTM         .0                  .0                  .0
RHORIZ        .0 SHORIZ        1.0    NPSURF        .0
  profile from Woods Hole, 1 m rounding, mod3 May 5,1990, 1, CVF
  ZERO SOUND-SPEED PERTURBATION
  BOTTOM DEPTH = 4.0 KM BELOW MSL
WH30    -6000       0       0      -1000 25132741     9000000     975000              0     0 14T
    -1320     40500       0       0     0     274269      274269       0       0     0     0  1M
    -1320     40500       0       0     0     274269      274269       0       0     0     0  2M
    -1320    525589       0       0     0    3550107     3550107       0       0     0     0  3M
    -1320    525589       0       0     0    3550107     3550107       0       0     0     0  4M
    -1320   1010678       0       0     0    6825945     6825945       0       0     0     0  5M
    -1320   1010678       0       0     0    6825945     6825945       0       0     0     0  6M
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	-1320	1495767	0	0	0	10101783	10101783	0	0	0	0	7M
	-1320	1495767	0	0	0	10101783	10101783	0	0	0	0	8M
	-1320	1980856	0	0	0	13377621	13377621	0	0	0	0	9M
	-1320	1980856	0	0	0	13377621	13377621	0	0	0	0	10M
	-1320	2465945	0	0	0	16653459	16653459	0	0	0	0	11M
	-1320	2465945	0	0	0	16653459	16653459	0	0	0	0	12M
	-1320	2951034	0	0	0	19929297	19929297	0	0	0	0	13M
	-1320	2951034	0	0	0	19929297	19929297	0	0	0	0	14M
WH30	-6000	0	0		-1000	25132741	9000000	1175000		0	0	14T
	-1000	29151	0	0	5558	198902	198902	0	0	0	0	1R
	-1000	43633	0	0	-5558	295195	295195	0	0	0	0	2R
	-1000	544952	0	0	5558	3678965	3678965	0	0	0	0	3R
	-1000	559434	0	0	-5558	3775258	3775258	0	0	0	0	4R
	-1000	1060753	0	0	5558	7159028	7159028	0	0	0	0	5R
	-1000	1075235	0	0	-5558	7255321	7255321	0	0	0	0	6R
	-1000	1576554	0	0	5558	10639091	10639091	0	0	0	0	7R
	-1000	1591036	0	0	-5558	10735384	10735384	0	0	0	0	8R
	-1000	2092355	0	0	5558	14119154	14119154	0	0	0	0	9R
	-1000	2106837	0	0	-5558	14215447	14215447	0	0	0	0	10R
	-1000	2608156	0	0	5558	17599217	17599217	0	0	0	0	11R
	-1000	2622638	0	0	-5558	17695510	17695510	0	0	0	0	12R
	-1000	3123957	0	0	5558	21079280	21079280	0	0	0	0	13R
	-1000	3138439	0	0	-5558	21175573	21175573	0	0	0	0	14R
WH30	-6000	0	0		-1000	25132741	9000000	1375000		0	0	14T
	-1000	23018	0	0	9080	158442	158442	0	0	0	0	1R
	0	34860	0	0	-2491	236919	236919	0	0	0	0	2A
	-1000	46701	0	0	-9080	315396	315396	0	0	0	0	2R
	-1000	576463	0	0	9080	3886742	3886742	0	0	0	0	3R
	0	588305	0	0	-2491	3965219	3965219	0	0	0	0	4A
	-1000	600146	0	0	-9080	4043696	4043696	0	0	0	0	4R
	-1000	1129908	0	0	9080	7615042	7615042	0	0	0	0	5R
	0	1141750	0	0	-2491	7693519	7693519	0	0	0	0	6A
	-1000	1153591	0	0	-9080	7771996	7771996	0	0	0	0	6R
	-1000	1683353	0	0	9080	11343342	11343342	0	0	0	0	7R
	0	1695195	0	0	-2491	11421819	11421819	0	0	0	0	8A
	-1000	1707036	0	0	-9080	11500296	11500296	0	0	0	0	8R
	-1000	2236798	0	0	9080	15071642	15071642	0	0	0	0	9R
	0	2248640	0	0	-2491	15150119	15150119	0	0	0	0	10A
	-1000	2260481	0	0	-9080	15228596	15228596	0	0	0	0	10R
	-1000	2790243	0	0	9080	18799942	18799942	0	0	0	0	11R
	0	2802085	0	0	-2491	18878419	18878419	0	0	0	0	12A
	-1000	2813926	0	0	-9080	18956896	18956896	0	0	0	0	12R
	-1000	3343688	0	0	9080	22528242	22528242	0	0	0	0	13R
	0	3355530	0	0	-2491	22606719	22606719	0	0	0	0	14A
	-1000	3367371	0	0	-9080	22685196	22685196	0	0	0	0	14R
WH30	-6000	0	0		-1000	25132741	9000000	1575000		0	0	14T
	-1000	19290	0	0	11921	134041	134041	0	0	0	0	1R
	0	25094	0	0	-8144	172964	172964	0	0	0	0	2A
	-1000	30898	0	0	-11921	211887	211887	0	0	0	0	2R
	-40000	208347	0	0	7216	1425339	1425339	0	0	0	0	3G
	-1000	385795	0	0	11921	2638791	2638791	0	0	0	0	3R
	0	391599	0	0	-8144	2677714	2677714	0	0	0	0	4A
	-1000	397403	0	0	-11921	2716637	2716637	0	0	0	0	4R
	-40000	574852	0	0	7216	3930089	3930089	0	0	0	0	5G
	-1000	752300	0	0	11921	5143541	5143541	0	0	0	0	5R
	0	758104	0	0	-8144	5182464	5182464	0	0	0	0	6A
	-1000	763908	0	0	-11921	5221387	5221387	0	0	0	0	6R
	-40000	941357	0	0	7216	6434839	6434839	0	0	0	0	7G
	-1000	1118805	0	0	11921	7648291	7648291	0	0	0	0	7R
	0	1124609	0	0	-8144	7687214	7687214	0	0	0	0	8A
	-1000	1130413	0	0	-11921	7726137	7726137	0	0	0	0	8R
	-40000	1307862	0	0	7216	8939589	8939589	0	0	0	0	9G

-1000	1485310	0	0	11921	10153041	10153041	0	0	0	0	9R
0	1491114	0	0	-8144	10191964	10191964	0	0	0	0	10A
-1000	1496918	0	0	-11921	10230887	10230887	0	0	0	0	10R
-40000	1674367	0	0	7216	11444339	11444339	0	0	0	0	11G
-1000	1851815	0	0	11921	12657791	12657791	0	0	0	0	11R
0	1857619	0	0	-8144	12696714	12696714	0	0	0	0	12A
-1000	1863423	0	0	-11921	12735637	12735637	0	0	0	0	12R
-40000	2040872	0	0	7216	13949089	13949089	0	0	0	0	13G
-1000	2218320	0	0	11921	15162541	15162541	0	0	0	0	13R
0	2224124	0	0	-8144	15201464	15201464	0	0	0	0	14A
-1000	2229928	0	0	-11921	15240387	15240387	0	0	0	0	14R

WH3-5 SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
2/28/1991 20h56m
.0 .0 CTANH 100.0 NPSPEED .0
GHORIZ 21.0 NPBOTM .0 .0 .0
RHORIZ .0 SHORIZ 1.0 NPSURF .0
profile from Woods Hole, 1 m rounding, mod3 May 5,1990, 1, CVF
ZERO SOUND-SPEED PERTURBATION
BOTTOM DEPTH = 4.0 KM BELOW MSL

WH30	-6000	0	0	-1000	25132741	9000000	975000			0	0	14T
	-1320	40505	0	0	0	274268	274268	0	0	0	0	1M
	-1320	40505	0	0	0	274268	274268	0	0	0	0	2M
	-1320	525593	0	0	0	3550106	3550106	0	0	0	0	3M
	-1320	525593	0	0	0	3550106	3550106	0	0	0	0	4M
	-1320	1010681	0	0	0	6825944	6825944	0	0	0	0	5M
	-1320	1010681	0	0	0	6825944	6825944	0	0	0	0	6M
	-1320	1495769	0	0	0	10101782	10101782	0	0	0	0	7M
	-1320	1495769	0	0	0	10101782	10101782	0	0	0	0	8M
	-1320	1980857	0	0	0	13377620	13377620	0	0	0	0	9M
	-1320	1980857	0	0	0	13377620	13377620	0	0	0	0	10M
	-1320	2465945	0	0	0	16653458	16653458	0	0	0	0	11M
	-1320	2465945	0	0	0	16653458	16653458	0	0	0	0	12M
	-1320	2951033	0	0	0	19929296	19929296	0	0	0	0	13M
	-1320	2951033	0	0	0	19929296	19929296	0	0	0	0	14M
WH30	-6000	0	0	-1000	25132741	9000000	1175000			0	0	14T
	-1000	29146	0	0	5558	198898	198898	0	0	0	0	1R
	-1000	43628	0	0	-5558	295191	295191	0	0	0	0	2R
	-1000	544948	0	0	5558	3678962	3678962	0	0	0	0	3R
	-1000	559430	0	0	-5558	3775255	3775255	0	0	0	0	4R
	-1000	1060750	0	0	5558	7159026	7159026	0	0	0	0	5R
	-1000	1075232	0	0	-5558	7255319	7255319	0	0	0	0	6R
	-1000	1576552	0	0	5558	10639090	10639090	0	0	0	0	7R
	-1000	1591034	0	0	-5558	10735383	10735383	0	0	0	0	8R
	-1000	2092354	0	0	5558	14119154	14119154	0	0	0	0	9R
	-1000	2106836	0	0	-5558	14215447	14215447	0	0	0	0	10R
	-1000	2608156	0	0	5558	17599218	17599218	0	0	0	0	11R
	-1000	2622638	0	0	-5558	17695511	17695511	0	0	0	0	12R
	-1000	3123958	0	0	5558	21079282	21079282	0	0	0	0	13R
	-1000	3138440	0	0	-5558	21175575	21175575	0	0	0	0	14R
WH30	-6000	0	0	-1000	25132741	9000000	1375000			0	0	14T
	-1000	23018	0	0	9080	158443	158437	0	0	0	0	1R
	0	34859	0	0	-2491	236920	236914	0	0	0	0	2A
	-1000	46701	0	0	-9080	315397	315392	0	0	0	0	2R
	-1000	576463	0	0	9080	3886743	3886738	0	0	0	0	3R
	0	588304	0	0	-2491	3965220	3965215	0	0	0	0	4A
	-1000	600146	0	0	-9080	4043697	4043693	0	0	0	0	4R
	-1000	1129908	0	0	9080	7615043	7615039	0	0	0	0	5R
	0	1141749	0	0	-2491	7693520	7693516	0	0	0	0	6A
	-1000	1153591	0	0	-9080	7771997	7771994	0	0	0	0	6R
	-1000	1683353	0	0	9080	11343343	11343340	0	0	0	0	7R
	0	1695194	0	0	-2491	11421820	11421817	0	0	0	0	8A

	-1000	1707036	0	0	-9080	11500297	11500295	0	0	0	0	8R
	-1000	2236798	0	0	9080	15071643	15071641	0	0	0	0	9R
	0	2248639	0	0	-2491	15150120	15150118	0	0	0	0	10A
	-1000	2260481	0	0	-9080	15228597	15228596	0	0	0	0	10R
	-1000	2790243	0	0	9080	18799943	18799942	0	0	0	0	11R
	0	2802084	0	0	-2491	18878420	18878419	0	0	0	0	12A
	-1000	2813926	0	0	-9080	18956897	18956897	0	0	0	0	12R
	-1000	3343688	0	0	9080	22528243	22528243	0	0	0	0	13R
	0	3355529	0	0	-2491	22606720	22606720	0	0	0	0	14A
	-1000	3367371	0	0	-9080	22685197	22685198	0	0	0	0	14R
WH30	-6000	0	0		-1000	25132741	9000000	1575000		0	0	14T
	-1000	19291	0	0	11921	134041	134041	0	0	0	0	1R
	0	25095	0	0	-8144	172965	172965	0	0	0	0	2A
	-1000	30899	0	0	-11921	211888	211888	0	0	0	0	2R
	-40000	208348	0	0	7216	1425339	1425339	0	0	0	0	3G
	-1000	385796	0	0	11921	2638791	2638791	0	0	0	0	3R
	0	391600	0	0	-8144	2677715	2677715	0	0	0	0	4A
	-1000	397404	0	0	-11921	2716638	2716638	0	0	0	0	4R
	-40000	574853	0	0	7216	3930089	3930089	0	0	0	0	5G
	-1000	752301	0	0	11921	5143541	5143541	0	0	0	0	5R
	0	758105	0	0	-8144	5182465	5182465	0	0	0	0	6A
	-1000	763909	0	0	-11921	5221388	5221388	0	0	0	0	6R
	-40000	941358	0	0	7216	6434839	6434839	0	0	0	0	7G
	-1000	1118806	0	0	11921	7648291	7648291	0	0	0	0	7R
	0	1124610	0	0	-8144	7687215	7687215	0	0	0	0	8A
	-1000	1130414	0	0	-11921	7726138	7726138	0	0	0	0	8R
	-40000	1307863	0	0	7216	8939589	8939589	0	0	0	0	9G
	-1000	1485311	0	0	11921	10153041	10153041	0	0	0	0	9R
	0	1491115	0	0	-8144	10191965	10191965	0	0	0	0	10A
	-1000	1496919	0	0	-11921	10230888	10230888	0	0	0	0	10R
	-40000	1674368	0	0	7216	11444339	11444339	0	0	0	0	11G
	-1000	1851816	0	0	11921	12657791	12657791	0	0	0	0	11R
	0	1857620	0	0	-8144	12696715	12696715	0	0	0	0	12A
	-1000	1863424	0	0	-11921	12735638	12735638	0	0	0	0	12R
	-40000	2040873	0	0	7216	13949089	13949089	0	0	0	0	13G
	-1000	2218321	0	0	11921	15162541	15162541	0	0	0	0	13R
	0	2224125	0	0	-8144	15201465	15201465	0	0	0	0	14A
	-1000	2229929	0	0	-11921	15240388	15240388	0	0	0	0	14R

Appendix D: File DINPX.SAM - The input data file
to HARPO to generate PUNCHX.SAM

```
JONES      RB3    X6464
WH3-1    SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
  1      6371.3868        EARTH RADIUS TO MSL, KM (6370.)
  3        -.6            TRANSMITTER HEIGHT ABOVE MSL (T=ABOVE BOTTOM), KM
  4         0.     AN KM  N. TRANSMITTER LATITUDE, KM
  5         0.     AN KM  E. TRANSMITTER LONGITUDE, KM
  7       400.     FQ HZ  INITIAL FREQUENCY, HZ
 11        90.     AN DG  INITIAL AZIMUTH ANGLE, DEG
 15         9.75   AN DG  INITIAL ELEVATION ANGLE, DEG
 16        15.75   AN DG  FINAL   ELEVATION ANGLE, DEG
 17         2.0    AN DG  STEP IN ELEVATION ANGLE, DEG
 19         0.            STOP RAYS THAT STRIKE BOTTOM (1=YES; 0=NO)
 20        -.6            RECEIVER HEIGHT ABOVE MSL, KM
 22         2.            MAXIMUM NUMBER OF HOPS (1.)
 23     99000.            MAXIMUM NUMBER OF STEPS PER HOP (1000.)
 26         5.            MAXIMUM RAY HEIGHT ABOVE MSL, KM
 27        -5.            MINIMUM RAY HEIGHT ABOVE MSL, KM
 28      3000.            MAXIMUM RANGE AT MSL, KM
 29         0.            DO:  EIGRAY/RNG-TIM/RNG-ELV/NEW-PROJ/RAYTRC/CONT/PROF
 33        20.            MAXIMUM ABSORPTION, DB (999.999)
 42         1.0E-09       MAXIMUM SINGLE-STEP INTEGRATION ERROR (1.0E-4)
 44          .01          INITIAL INTEGRATION STEP SIZE, KM (1.0)
 57         2.            PHASE PATH  (0=NO; 1=INTEGRATE; 2=INTEGRATE/PRINT)
 58         0.            ABSORPTION  (0=NO; 1=INTEGRATE; 2=INTEGRATE/PRINT)
 60         0.            PATH LENGTH (0=NO; 1=INTEGRATE; 2=INTEGRATE/PRINT)
 71       100.            NUMBER OF INTEGRATION STEPS PER PRINT [1.E9]
 72         1.            OUTPUT RAYSETS (1=YES; 0=NO)
 73         0.            DIAGNOSTIC PRINTOUT (1=YES; 0=NO)
 74         0.            PRINT EVERY W(71) RAY STEPS (0=YES; 1=N0)
 76         0.            BINARY RAY OUTPUT (1=YES; 0=NO)
 77        76.            LINES PER PAGE OF PRINTOUT = 76. FOR HPLJ (57.)
 81         4.            RAYPLOT PROJECTION PLANE (4 = VERT. RECTANGULAR)
 82        30.             PLOT-ORDINATE EXPANSION FACTOR [1.]
 83         0.     AN KM   N. LATITUDE OF LEFT PLOT EDGE, KM
 84         0.     AN KM   E. LONGITUDE OF LEFT PLOT EDGE, KM
 85         0.     AN KM   N. LATITUDE OF RIGHT PLOT EDGE, KM
 86       100.     AN KM   E. LONGITUDE OF RIGHT PLOT EDGE, KM
 87        10.     AN KM   DISTANCE BETWEEN RANGE TICKS, KM
 88        -4.             HEIGHT ABOVE MSL OF BOTTOM OF GRAPH, KM
 89         0.             HEIGHT ABOVE MSL OF TOP OF GRAPH, KM
 96         1.             DISTANCE BETWEEN DEPTH TICKS, KM
150         7.            CTANH SOUND SPEED MODEL CHECK NUMBER
152       100.             CTANH BACKGROUND SOUND SPEED DATA SET ID
 -3                       DATA SUBSET FOR BACKGROUND SOUND-SPEED MODEL
  A  profile from Woods Hole, 1 m rounding, mod3 May 5,1990, 1, CVF
  3     999.0
   LN  M         LN  M         LN  M
      -0.00   1520.84          0.0
     -10.00   1520.66         -1.0
     -20.00   1520.28         -1.0
     -30.00   1519.33         -1.0
     -50.00   1512.44         -1.0
     -75.00   1505.78         -1.0
    -100.00   1503.17         -1.0
    -125.00   1501.06         -1.0
    -150.00   1498.31         -1.0
    -200.00   1491.90         -1.0
    -250.00   1489.08         -1.0
```

```
   -300.00   1486.76         -1.0
   -400.00   1482.14         -1.0
   -500.00   1479.35         -1.0
   -600.00   1478.51         -1.0
   -700.00   1478.65         -1.0
   -800.00   1479.04         -1.0
   -900.00   1479.64         -1.0
  -1000.00   1480.27         -1.0
  -1100.00   1481.05         -1.0
  -1200.00   1481.89         -1.0
  -1300.00   1482.82         -1.0
  -1400.00   1483.74         -1.0
  -1500.00   1484.66         -1.0
  -1750.00   1487.46         -1.0
  -2000.00   1490.59         -1.0
  -2500.00   1497.99         -1.0
  -3000.00   1506.03         -1.0
  -3500.00   1514.42         -1.0
  -4000.00   1523.21         -1.0
  -4500.00   1532.23         -1.0
  -5000.00   1541.43          0.0
  999.0
 0      RETURN TO W-ARRAY DATA SET
175       0.           NPSPEED SOUND SPEED PERTURBATION MODEL NUMBER
177       0.           NPSPEED PERTURBATION SOUND SPEED DATA SET ID
 -4                    DATA SUBSET FOR SOUND-SPEED PERTURBATION MODEL
  A  ZERO SOUND-SPEED PERTURBATION
 0      RETURN TO W-ARRAY DATA SET
275       1.           RHORIZ RECEIVER MODEL CHECK NUMBER
 -8                    DATA SUBSET FOR RECEIVER-SURFACE MODEL
  A  RECEIVER SURFACE = SPHERE 600 M BELOW MSL
 0      RETURN TO W-ARRAY DATA SET
300       1.           GHORIZ BOTTOM MODEL CHECK NUMBER
302      21.           GLORENZ BOTTOM MODEL DATA SET ID
 -9                    DATA SUBSET FOR BACKGROUND BOTTOM MODEL
  A  BOTTOM DEPTH = 4.0 KM BELOW MSL
 0      RETURN TO W-ARRAY DATA SET
303      -4.            HEIGHT OF BOTTOM ABOVE MSL, KM
325       0.           NPBOTM MODEL CHECK NUMBER
-10                    DATA SUBSET FOR BOTTOM PERTURBATION MODEL
  A  NO BOTTOM PERTURBATION
 0      RETURN TO W-ARRAY DATA SET
350       1.           SHORIZ MODEL CHECK NUMBER
352       1.            SHORIZ OCEAN SURFACE DATA SET ID
-11                    DATA SUBSET FOR OCEAN SURFACE MODEL
  A  OCEAN SURFACE = SPHERE AT MSL
 0      RETURN TO W-ARRAY DATA SET
353       0.            HEIGHT OF OCEAN SURFACE ABOVE MSL, KM
375       0.           NPSURF MODEL CHECK NUMBER
-12                    DATA SUBSET FOR OCEAN SURFACE PERTURBATION MODEL
  A  NO OCEAN SURFACE PERTURBATION
 0      RETURN TO W-ARRAY DATA SET
 0                     **********  END OF RUN SET NUMBER 1  *********
WH3-2   SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
 22       10.          MAXIMUM NUMBER OF HOPS (1.)
 0                     **********  END OF RUN SET NUMBER 2  *********
WH3-3   SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
 20      -.1           RECEIVER HEIGHT ABOVE MSL, KM
 22       3.           MAXIMUM NUMBER OF HOPS (1.)
 -8                    DATA SUBSET FOR RECEIVER-SURFACE MODEL
  A  RECEIVER SURFACE = SPHERE 100 M BELOW MSL
 0      RETURN TO W-ARRAY DATA SET
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  0                          **********  END OF RUN SET NUMBER 3  *********
WH3-4   SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
 22         10.              MAXIMUM NUMBER OF HOPS (1.)
  0                          **********  END OF RUN SET NUMBER 4  *********
WH3-5   SAMPLE RAYPATH CALCULATIONS FOR HARPX SAMPLE CASE, 12 July 1990
 22         14.              MAXIMUM NUMBER OF HOPS (1.)
  0                          **********  END OF RUN SET NUMBER 5  *********
```