Project "Seismic microzoning of Latin America cities"
ICTP Network NET-58
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COMPUTATION OF SYNTHETIC SEISMOGRAMS

Users' guide

First version, May 2005
Second version, May 2006
Third version, September 2006
Fourth version, December 2006
Fifth Version, December 2007
Sixth Version, December 2008
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I) 1D LAYERED STRUCTURAL MODELS
WITH THE MODAL SUMMATION (MS) TECHNIQUE
A quick reference guide
December 2007 version (not changed in Dec. 2008)

Programs in Linux based computers of ICTP

This version was prepared for the case of remote access, running in Linux platform on ICTP computers. Then, it was eliminated from FFT calculations the need of copying each time the Gusev curves in the working directory. It has the advantage of using always the same curves without the possibility of passing from standard curves to special ones. If that is the case, you can't use the program nfft bringing the proper Gusev curves instead of the nfftm that we use. For knowing about the remote access commands to ICTP computers you can consult

http://scs.ictp.it/howto/remote_access.html

The specific programs for main calculation were written and compiled in FORTRAN 77. The plotting scripts use the GNUPLOT, version 4.0 and the GMT, version 4.0. You will need to add to your ICTP ".cshrc" file the lines:

```
setenv PATH /afs/ictp.trieste.it/public/l/leoalvar/SMLAC/binLinux:$PATH
setenv GMTHOME /afs/ictp.trieste.it/public/l/leoalvar/SMLAC/bin386/GMT4.0
set path=(/afs/ictp.trieste.it/public/l/leoalvar/SMLAC/bin386/GMT4.0/bin
                                                                  $path)
```

and optional, only if IDL programs will be used for other plots (not described in this manual), the following:

```
source /afs/ictp.trieste.it/public/l/leoalvar/SMLAC/bin386/idl/idl/bin
                                                          /idl_setup
setenv IDL_PATH /afs/ictp.trieste.it/public/l/leoalvar/SMLAC/SOURCEidl:
             /afs/ictp.trieste.it/public/l/leoalvar/SMLAC/bin386/idl/idl/lib
```

The access to ICTP computers is allowed only trough ssh. Use your computer account for it.

Foreword

In the following, the process of computing synthetic seismograms for a 1D layered model is described. In the example, the model name is assumed to be "n_o_s" (**n**ame **o**f **s**tructure), so all filenames refer to that. Change the model name to whatever fit your needs if you run your own test. All the filenames will change accordingly. PostScript files generated at any step can be: - visualized on screen with the gs or gv commands

- converted to pdf format with the ps2pdf command
- printed with the lpr command

Computation of normal modes for 1D layered structural models

Files required:

```
p2r.par      Parameter file for program p2rm.out
n_o_s.stp    Definition of layer properties (example of a simple 2D structure)
```

Steps:

1) Edit file n_o_s.stp to define the layer properties (you should substitute it by your particular structure definition); for example, this one:

```
  thk(km) rho  Vp(km/s) Vs(km/s)   Qp     Qs  depth(km) layer
```

```
 2.0000  2.80 4.800000 2.400000 400.00 200.00 2.00000  1
 2.0000  2.83 5.800000 3.300000 400.00 200.00 4.00000  2
 2.0000  2.84 6.200000 3.500000 400.00 200.00 6.00000  3
 8.0000  2.85 5.700000 3.300100 400.00 200.00 14.00000 4
 2.0000  2.86 6.200000 3.550000 400.00 200.00 16.00000 5
21.0000  2.87 6.500000 3.700000 400.00 200.00 37.00000 6
 3.0000  2.90 7.000000 4.000000 400.00 200.00 40.00000 7
 3.0000  3.10 7.500000 4.300000 400.00 200.00 43.00000 8
40.0000  3.35 8.100000 4.500000 400.00 200.00 83.00000 9
```

Notes

- The structure should reach at least 80 km in depth for 10 Hz computations, and about 1000 km for 1 Hz computations
- The Vs of the bottom layer should be about 4.5 km/s for 10 Hz computations and about 6.4 km/s for 10 Hz computations

2) Edit file p2r.par so that the file n_o_s.stp is used:

```
 Parameters file for program p2r
0.         reference structure (0 = none)
10.        max frequency (1 or 10 Hz)
4.50       min velocity for halfspace (1Hz=6.42,10Hz=4.50)
n_o_s.stp  physical layers first structure
```

Notes

- To begin with, do not specify a reference structure, but describe the layer properties in .stp files down to the required depth. Change the name n_o_s.stp by your own structure

3) Run program **p2rm.out** that will generate the file name_of_structure.str, that is required by programs lov and ray to compute the modes. From this moment all the files will have in some part of their names the "n_o_s (except some parameter files).

4) You can plot the structure (density and velocities vs depth) issuing the command

```
gnuplot n_o_s.str.gplot
```

A file n_o_s.str.ps is created that can be printed or viewed. You can edit file n_o_s.str.gplot to redefine the depth range and/or the density and velocity ranges, save it and issue the gnuplot command again.

5) Run programs **ray** and **lov** to generate the modes for Love and Rayleigh waves.

```
lov
ray
```

6) Plot the modes and check that all modes have been computed:

```
gnuplot n_o_s.gspl     generate the PostScript file n_o_s.spl.ps -
                       (Love modes)
gnuplot n_o_s.gspr     generate the PostScript file n_o_s.spl.ps -
                       (Rayleigh modes)
gs n_o_s.spl.ps        (visualize on screen Love modes)
gs n_o_s.spr.ps        (visualize on screen Rayleigh modes)
lpr n_o_s.spl.ps       (print Love modes)
lpr n_o_s.spr.ps       (print Rayleigh modes)
```

You have to analyse carefully the graphics n_o_s.spl.ps and n_o_s.spr.ps. They have to show a smooth behaviour in phase velocities. If these graphics show holes or other non regular characteristics, you have to check your structure.

Visualization of the eigenfunctions (displacements only) for selected modes and frequencies (this is an optional step):

Files required :

```
eigplotl.par      Parameters defining the range of modes and frequencies
                  for Love eigenfunctions
eigplotr.par      Parameters defining the range of modes and frequencies
                  for Rayleigh eigenfunctions
n_o_s.spl         Modes for Love waves
n_o_s.spr         Modes for Rayleigh waves
```

Steps:

1) Edit file eigplotl.par and eigplotr.par to define the ranges for modes and frequencies for Love and Rayleigh modes:

```
Parameters file for computation of eigenfunctions (eigplotl)
------------------------------------------------------------
n_o_s.spl Modes for Love waves
1 2 1.00 1.050 0 first mode,last mode,first freq,last freq,iend
Parameters file for computation of eigenfunctions (eigplotr)
------------------------------------------------------------
n_o_s.spr Modes for Love waves
1 2 1.00 1.050 0 first mode,last mode,first freq,last freq,iend
```

Notes

- To begin with, let iend=0, that is use the amount of structure automatically selected by programs lov and ray
- In each parameter file, more lines defining mode and frequency ranges can be defined

2) Run programs **eigplotl.out** and **eigplotr.out** to generate the eigenfunctions

3) Plot the eigenfunctions:

```
gnuplot eigplotl.gplot  (plot v/v(0) vs depth)
gnuplot eigplotr.gplot  (plot u/w(0) and w/w(0) vs depth)
gs eigu.ps              visualize on screen u/w(0) vs depth, with Vs
                        (plotted as well)
gs eigv.ps              visualize on screen v/v(0) vs depth, with Vs
                        (plotted as well)
gs eigz.ps              visualize on screen w/w(0) vs depth, with Vs
                        (plotted as well)
lpr eigu.ps             print u/w(0) vs depth, with Vs (plotted as well)
lpr eigv.ps             print v/v(0) vs depth, with Vs (plotted as well)
lpr eigz.ps             print w/w(0) vs depth, with Vs (plotted as well)
```

Parametric test for computation of synthetic seismograms in 1D layered structural models

This test is intended for analysing the way in which your selection of initial data will influence in your end results. You can vary parameters concerning source and trajectory source-profile. At the end you should select for passing to 2D calculations a combination of parameters that guarantees that both P-SV and SH waves are clearly expressed over the noise level (to avoid to be placed in the "silence zone" of the radiation patterns). Sometimes you have to arrive to a compromise that can be of 2 kinds:

- ✔ to change the focal mechanism parameters in a way that both SH and P-SV waves has an acceptable amplitude
- ✔ to change the focal mechanism parameters twice, with some values for SH waves and with another values for P-SV waves

Files required:

```
paratest.par      Parameters defining the test
```

```
n_o_s.spl         Modes for Love waves
n_o_s.spr         Modes for Rayleigh waves
```

Steps:

1) Edit file paratest.par

```
Parameter file for program paratest
----------------------------------------
t_l               test label (root for output filenames - 13 chars max)
0                 Ref box file for values not listed below(0=no,13char.max)
n_o_s.spl         Love spectrum file
n_o_s.spr         Rayleigh spectrum file
3                 Motion (1=displ, 2=vel, 3=acc)
SRE 1 0 345 15    Strike (loop 0=no,1=yes, start, stop, step) (Degrees)
DIP 0 45 90 5     Dip (loop 0=no,1=yes, start, stop, step) (Degrees)
RAK 0 90 90 15    Rake (loop 0=no,1=yes, start, stop, step) (Degrees)
SDE 0 5 10 1      Source Depth (loop 0=no/1=yes, start, stop, step) (km)
EDI 0 20 100 10   Epicentral Distance(loop 0=no/1=yes,start,stop,step)(km)
RDE 0 0 20 2      Receiver Depth (loop 0=no/1=yes, start, stop, step) (km)
MOD 0 0 0 1       Modes (loop 0=no/1=yes, start, stop, step (must be 1) )
INT 0 0 9 1       Interpolation (0-9) (flag 0=no,1=yes, start, stop, step)
MAG 0 5.0 5.5 .1  Magnitude (flag 0=no,1=yes, start, stop, step)
```

Notes

- Parameters that can be varied:

```
SRE – strike/receiver angle (°)
DIP – fault dip angle (°)
RAK – fault rake angle (°)
SDE – source depth (km)
EDI – epicentral distance (km)
RDE – receiver depth (km)
MOD – modes to use (0 0 means all)
INT – interpolation in  frequency domain (number of samples to  add
      between two original samples)
MAG – magnitude
```

- Only one parameter can be activated for the loop in one run of program paratest.out, and is chosen by placing a 1 in the first numeric field. All other parameters must have a 0 in the first numeric field. In the above example the strike/receiver angle is varied between 0° and 345° with step 15°. For the parameters that are not varied, the value of the second numeric field is taken. That is: dip 45°, rake 90°, source depth 5 km, etc...
- To begin with, there is no need to define a reference box
- For a graphical description of the FPS parameters see the scheme in page 8

2) Run program **paratestm.out**

This program will prepare a script (name parajob) for the calculation of synthetic seismograms (transverse, radial and vertical components). The script will look like:

```
date>t_lparajob.pri
echo "Start of parajob job">>t_lparajob.pri
cp syr.cntl.r syr.cntl
echo "Computing Radial Component..."
syr0048.out
date>>t_lparajob.pri
echo "Radial Computed">>t_lparajob.pri
cp syr.cntl.z syr.cntl
echo "Computing Vertical Component..."
syr0048.out
date>>t_lparajob.pri
echo "Vertical Computed">>t_lparajob.pri
cp syl.cntl.t syl.cntl
echo "Computing Transverse Component..."
```

```
syl0048.out
date>>t_lparajob.pri
echo "Transverse Computed">>t_lparajob.pri
date>>t_lparajob.pri
echo "Scaling seismograms..."
nfftm.out
date>>t_lparajob.pri
paraplotm.out
gnuplot t_l.mod.gplot
echo " "
sisplot.pl
echo "*** To plot the peak values: gs t_l.3CC.ps"
echo "*** To plot the seismograms: gs t_l.3CC.sis.*.ps"
```

Note that the name of this two files is formed with the test label "t_l" name plus the "3 characters code" (3CC) of varied parameter in the test (in non capital letters). It is important, if you are making an extensive test of parameters, that you don't repeat the t_l for similar parameter.

3) Run the script **parajob** with command:

```
sh parajob
```

The script calls the programs **syl0048.out** (for transverse component) **syr0048.out** (for radial and vertical components), **nfftm.out** for scaling the seismograms according to magnitude, and **paraplotm.out** (for preparing the gnuplot scripts for plotting amplitudes and seismograms). Be sure to have the files with Love and Rayleigh modes in the working directory before running the script.

4) Look at the postscript files generated by "gnuplot", issuing the "gs" or "gv" commands.

The process for selecting a right combination of parameters for the 2D calculations is to begin with a real FPS solution and depth of earthquake, and varying them looking for a combination that gives enough amplitudes in all components. This is done by analysing the files "t_l.3CC.ps" and "t_l.3CC.sis.ps". In the first you can see the maximum amplitudes of the synthetic seismograms as a function of the varied parameter, while in the second you can see the corresponding seismograms. In this graphic the varied parameter increases from top to bottom.

Automatic run of the 1D process for the case of remote access

The program " p2rm" creates two additional files: "job1D" and "job1Da" with the sequence of command lines above presented, with the exception of the ones corresponding to eigenfunctions calculations. The whole 1D process is limited then to execute "sh job1D", while the analysis of parameters influence on seismograms is done by executing consecutively "sh job1Da" after modifying the file "paratest.par". They can be executed also in the background through "sh job1D &" or "sh job1Da &", but they should late short time and it is better to wait for the results directly. The obtained graphs are put in a file compressed with "bzip2" that cans be easily decompressed in any Unix or Linux platform (some Windows programs can decompress them also – e.g., the free Izarc or 7-zip). It should be transferred for their posterior analysis at home institutions and for writing reports or papers.

Although job1D executes all the operations described in the manual, in the case of eigenfunctions calculations, corresponding lines are "commented" and you have to uncomment them if you want to obtain such plots. Nevertheless, they are only obtained for the first mode and last frequency. If it is desired to calculate other eigenfunctions the input files "eigplotl.par" y " eigplotr.par" should be modified according to the above described and to run the corresponding programs.

The script job1D ends with the message:

```
"your .ps graphs are in ps1D.tar.bz2"
```

while the script job1Da ends with a message

```
"your .ps graphs are in ps1Da.tar.bz2"
```

For doing the process you need:

- to create a working directory
- to copy in this directory the files " p2r.par" with the specifications for creating the structure, " your_structure.stp" with the physical properties by layer of the structure and "paratest.par" with the specifications for the source, that you should have to prepare before
- to run " p2rm.out" and immediately "sh job1D"
- to transfer your results: "ps1D.tar.bz2"
- to analyse carefully the "n_o_s.spl.ps" and n_o_s.spr.ps"; don't continue unless you are satisfied with the shape of this graphics
- Optional: to modify your file paratest.par, to run "sh job1Da" and to transfer the file "ps1Da.tar.bz2" (change the name of the transferred file if you are doing consecutive changes of paratetest.par)

Graphics obtained in a run

`n_o_s.spl.ps`	`spectrum for Love waves (c,u,I,a)`
`n_o_s.spr.ps`	`spectrum for Rayleigh waves (c,u,I,a, e)`
`n_o_s.sre.ps`	`maximum amplitude of synthetic seismograms as a function of the parameter varied in "paratest.par"`
`n_o_s.sre.sis.1.ps`	`synthetic seismograms for the different values of varied parameter, ordered, as parameter increases from top to bottom`
`n_o_s.str.ps`	`structure in depth (r,Vp,Vs)`

If eigenfunctions calculations are enabled, you will obtain also:

`eigu.ps`	`eigenfunctions for Rayleigh waves (displacement u)`
`eigv.ps`	`eigenfunctions for Rayleigh waves (displacement w)`
`eigw.ps`	`eigenfunctions for Love waves (displacement v)`

The name of the 3rd and 4th files are controlled by parameters in paratest.par file.

Contact persons:

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Leonardo Alvarez (Centro Nacional de Investigaciones Sismológicas, Cuba) – leoalvar@chcenais.cu, leoalvar@ictp.it

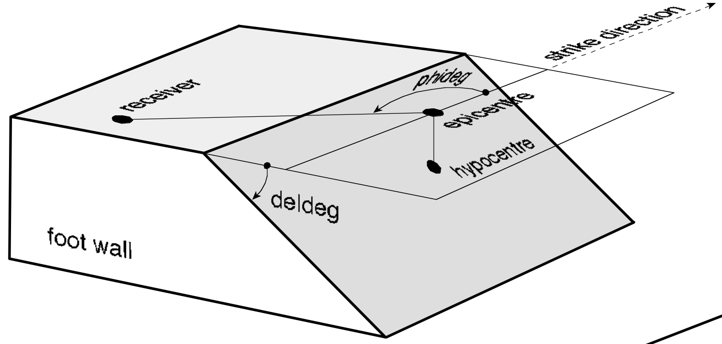
Use both e-mail addresses in the case of L. Alvarez

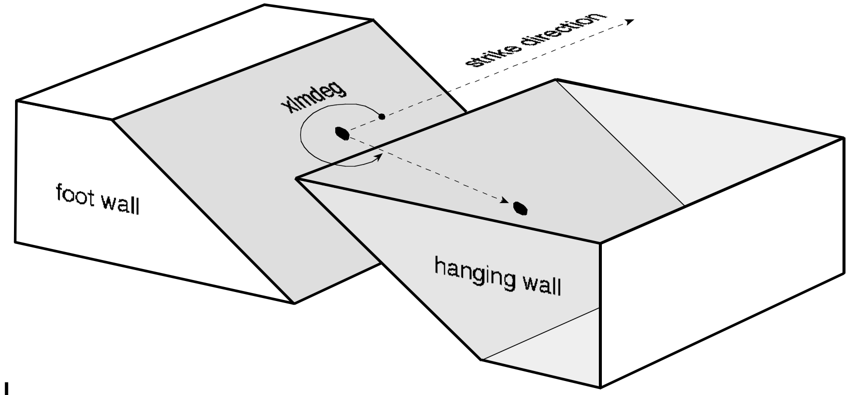
Abbreviations used

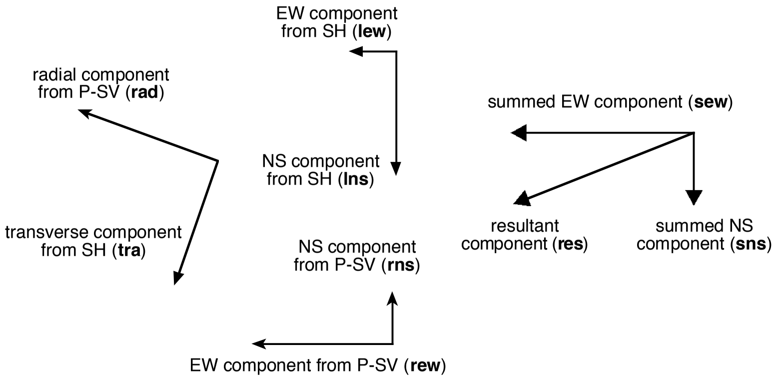
n_o_s – name of structure,
t_l – test label
3CC – 3 character code of parameter varied in "paratest" run

Definition of angles:

```
phideg: strike-receiver
deldeg: dip
xlmdeg: rake
phide2: strike of the fault
phide3: phideg-phide2
```



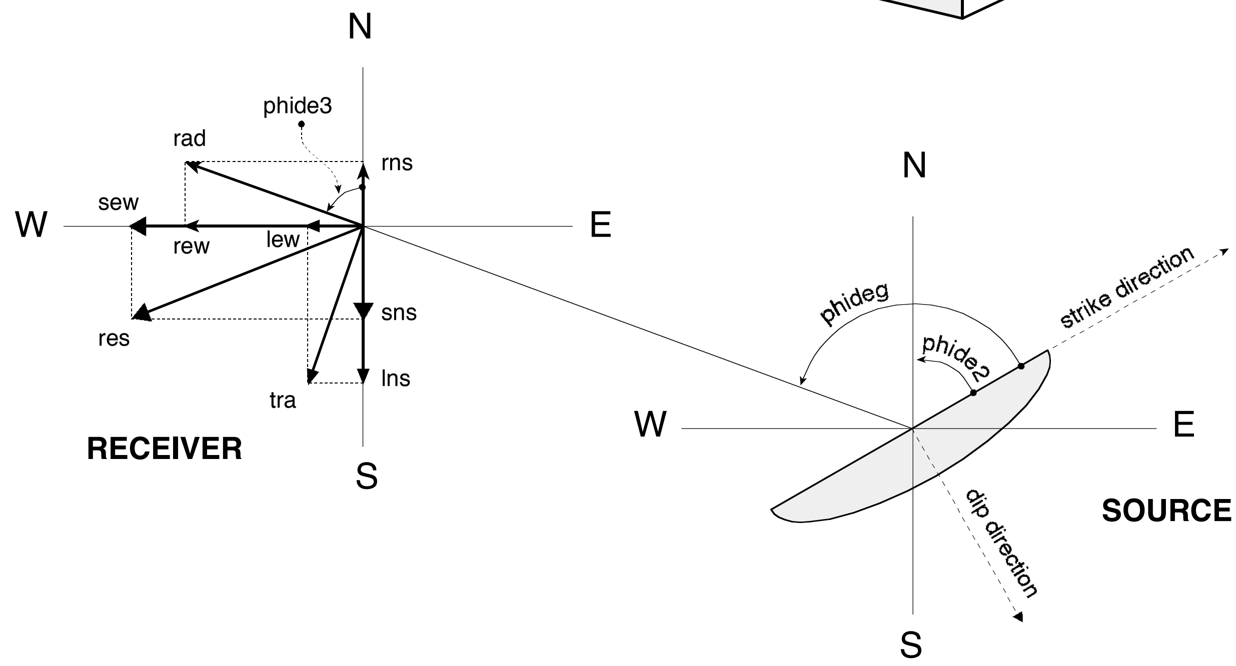




Positive direction of components:

```
rad: in the propagation direction
tra: to the left of propagation direction
 NS: North
 EW: West

Vertical component (not represented): up
```



Rotation and sum of horizontal components:

```
rns =  rad*cos(phide3)
rew =  rad*sin(phide3)
lns = -tra*sin(phide3)
lew =  tra*cos(phide3)

sns =  rns+lns
sew =  rew+lew
```

II) 2D LATERALLY HETEROGENEOUS MODELS WITH THE HYBRID TECHNIQUE (MODAL SUMMATION - FINITE DIFFERENCES)

A quick reference guide

December 2008 version, modified in November 2009

Programs in Linux based computers of ICTP

- This version was prepared for the case of remote access, running in Linux platform on ICTP computers. Then, it was eliminated from FFT calculations the need of copying each time the Gusev curves in the working directory. It has the advantage of using always the same curves without the possibility of passing from standard curves to special ones. If that is the case, you can't use these programs compiled for Linux. In order to differentiate the program pfdg9 for remote access from the one for online running it was renamed as pfdg9m.
- For avoiding problems when calculating long profiles, the programs finit and finray were changed for another versions which allows to processes longer profiles and greater source-profile distances. Now the programs are finit56b.out and finray53b.out and the maximum number of grid points in x direction is 4000 instead 2800. Do not forget to update your pfdg9.par file
- For knowing about the remote access commands to ICTP computers you can consult http://scs.ictp.it/howto/remote_access.html
- There were added several features, in particular the selection of single valued 2D/1D ratios of several ground motion parameters with a correlation analysis for testing independence, the selection and packing of some files that can be used as input for generating initial matrixes for curves classification with program P4, and the writing of some files with 2D data for preparing an scenario for the city (see part IV of this manual - in preparation, Dec. 2007)

The specific programs for main calculations were written and compiled in FORTRAN 77. The plotting scrips, written mainly in perl, use the GNUPLOT, version 4.0 and the GMT, version 4.0. Also there are some optional programs that need IDL plotting system. You will need to add to your ICTP ".cshrc" file the lines:

```
setenv PATH /afs/ictp.trieste.it/public/l/leoalvar/SMLAC/binLinux:$PATH
setenv GMTHOME /afs/ictp.trieste.it/public/l/leoalvar/SMLAC/bin386/GMT4.0
set path=(/afs/ictp.trieste.it/public/l/leoalvar/SMLAC/bin386/GMT4.0/bin
                                                                  $path)
```

and optionally, only if IDL programs will be used for other plots (not described in this manual), the following:

```
source /afs/ictp.trieste.it/public/l/leoalvar/SMLAC/bin386/idl/idl/bin
                                                           /idl_setup
setenv IDL_PATH /afs/ictp.trieste.it/public/l/leoalvar/SMLAC/SOURCEidl:
             /afs/ictp.trieste.it/public/l/leoalvar/SMLAC/bin386/idl/idl/lib
```

These settings are different from the ones presented in previous versions of this manual. The reason of the change is that ICTP will remove the disk were the programs were placed before.

Foreword

In the following, the process of computing synthetic seismograms for a 2D laterally heterogeneous model is described. In the example, the **n**ame **o**f the **m**odel is assumed to be

“n_o_m”, so all file names refer to that. Change the model name to whatever fits your needs if you run your own test. All the file names will change accordingly.
Before accepting the results obtained with the hybrid technique for the laterally heterogeneous model, a test is necessary where synthetic seismograms are computed for a laterally homogeneous model with the modal summation and with the hybrid techniques. If an acceptable fit is obtained using the two techniques for the laterally homogeneous model, the results obtained with the hybrid technique for the laterally heterogeneous model can be generally trusted.

Digitization of the laterally heterogeneous model with DigiMac program for Macintosh

Program DigiMac prepares a file with polygons that describe the heterogeneities (file .pof).
Files required:
model.tiff - A sketch of the model, acquired with a scanner, fitting on A4 paper. Can be in tiff, bitmap or pict format
Notes: usually a resolution of 72 dpi is enough when scanning the sketch for later on-screen digitization with program XDigiMac.
Steps: This is best done using program XDigiMac. The task is to draw filled polygons describing the heterogeneities, each with a uniform colour associated with the layer properties.

- Launch XDigiMac
- Open the image file with the sketch of the model (File --> Open --> Pict)
- Calibrate the image so that real world coordinates are associated with pixel coordinates
- Draw your model so that the source is located to the left of it. Use different colours for different materials; no black lines or sparse white pixels separating the different units.
- Prepare the legend for material properties: density (g/cm3), Vp and Vs (km/s), Qp and Qs. Colours in the legend should match exactly the colours used for drawing the model (RGB components). If you have an "Air" layer that describe topography, all of its properties must be set equal to 0.
- Digitize each polygon by clicking with the "Polygon Digitizer Tool" inside each polygon. Start with the "Air" polygon that defines the topography, if present.
- Save the polygon set to disk (Data --> Polygons --> Save Current Set), using extension .pof (example: svalpg1.pof)

Notes:

- By default, polygons are stored in ~/Documents/DigiFiles/ and should have extension .pof
- Before digitizing the polygons it's a good idea to clear the polygon memory (Data --> Polygons --> Forget All Polygons)

--> Contact Franco Vaccari if you want to use this program, and ask him about more detailed instructions (file DigiMacHelp.pdf)

Creation of the profile file using Linux and Windows programs

1) For the creation of the profile description file, first of all, you have to digitize it. The rules for digitization are simple:

- each area in profile have to be digitized in a closed contour (first point identical to last one) and saved in an independent file
- two neighbour areas has to be digitized by using the same points in the contact between them

- for the digitalization can be used any program (a GIS, a CAD type program, etc.)
- if you use a Windows program for digitizing, be sure of converting the output files to UNIX format

At the end you will have “n” files with the closing contours describing the different areas present in your profile. In general is preferred to name these files as “.bln” (program messages refer to them in this way), but you can give any name to them.

2) Use program “**bln2pof.out**” for creating the input .pof file. This program uses an input file “bln2pof.inp” were you have to give the data about the physical properties (density, V_P, V_S, Q_P, Q_S) and the name of the digitized contour for each area. The last version of the program also plots the model in three variants: with colour filled areas, with colour lines and with colour lines and the points defining them. These plots can be used for checking the model. The program also creates the input file plcontour.inp for the plcontour.pro IDL program. The output “.pof” file is compatible with DigiMac format and can be visualised using this Mac program.

3) You can use **IDL** program “plcontour.pro” for plotting the digitized profile. It uses the input file plcontour.inp and your contour files. In plcontour.inp you define the name of the ouput “.ps” file. If you are working in Linux this step is unnecessary because the last version of program “bln2pof” does the plot.

4) Check carefully the output “.ps” file. It is preferred to see it in the display in order that the image be zoomed as desired. If you don't find any error in the plot you can continue.

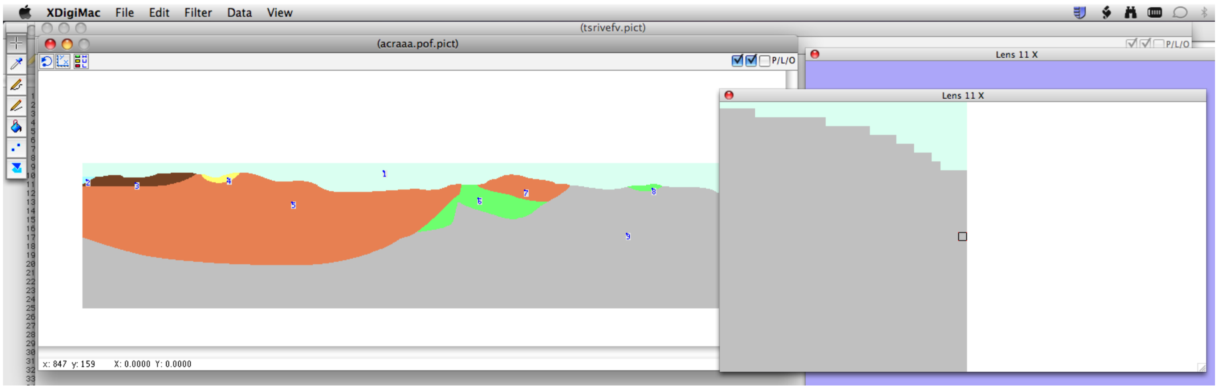
Notes:

- In ICTP network you can access to program bln2pof and to IDL program plcontour.pro. For the first case you have to run “bln2pof.out” and for the second there is a two step procedure. First, you have to run “idl” and then your prompt is changed to “IDL>”; in that prompt you have to write “plcontour.pro” and the program runs. After running, you should return to your original prompt by “exit”.
- There is possible to obtain Windows versions of program bln2pof and plcontour.pro. Last version of bln2pof makes use of gnuplot for plotting the graphs and is not tested in Windows yet. A demo version of IDL for Windows is also available. Contact L. Alvarez for them.
- You may desire an additional control of the quality of your .pof files. For this it is recommended to use the “**DigiMac**” program for Macintosh. Contact F. Vaccari for that. Program bln2pof creates an output compatible with DigiMac output files that can be visualized by it.
- You can plot the model in “.pof “ format by using the program **plotpof.out**. It only requieres as input a file “plotpof.inp” with the list of files to be plotted.

Digitizing of profiles in the case of use of topography

For considering topography in your profile it is mandatory to add an air layer that touches the free surface and extends to a little bit mor that the maximum topographic height. This layer should be the first in .pof file. All the physical properties of this layer should be set as 0.

When digitizing, the value y=0 can be fixed in any point from the beginning of profiles, and the sign conveying is positive downwards and negative upwards. Program pfdg9 adjust the input to the proper values (see enclosed fig.)



Computation of synthetic seismograms

Several programs must be used to generate the seismograms with the modal summation and the finite differences techniques. Program **pfdg9m.out** exists to easy up the whole process. It generates several scripts and all the input files required by those scripts at runtime.

Files required:

```
n_o_s.spl         Modes for Love waves
n_o_s.spr         Modes for Rayleigh waves
n_o_p.pof   Polygons describing the lateral heterogeneities
pfdg9.par         Parameters describing the modelling
```

Note: "n_o_s" means "**n**ame **o**f **s**tructure" as defined in part I of this manual, while "n_o_p" means "**n**ame **o**f **p**rofile".

Contents of pfdg9.par

```
Parameters file for program pfdg9
---------------------------------------------------------------------------
Modal summation model
---------------------------------------------------------------------------
venez.spr                          Modes for 1D structure
0          First mode to use (1=fundamental, 0=all)
0          Last mode to use (0=all)
5.0       Low pass filter cutoff frequency (xcutof)
.50        Ratio between filter's max freq with unit response and xcutof
.02        Low pass filter amplitude at cutoff
0          Interpolation for modal summation part
20.000      Source depth (km)
80.0      strike-receiver angle (SH modelling)
72.0       fault dip              (SH modelling)
160.0       fault rake              (SH modelling)
50.0      strike-receiver angle (P-SV modelling)
72.0       fault dip              (P-SV modelling)
160.0       fault rake              (P-SV modelling)
45.0        Source-2D model origin distance (km)
7.0        Magnitude
---------------------------------------------------------------------------
Finite differences model
---------------------------------------------------------------------------
n_o_m                          name of generated FD model
n_o_p.pof                      name of profile - Polygons with 2D part definition
4000       Max number of grid points along x
600        Max number of grind points along z
0          Force an air layer of 5 grid points without topography (0=no, 1=yes)
0.0        Min velocity (km/s) for grid definition (0=auto -> look for min Vs)
0          FD model length from 1st column of seismograms (km) (0=auto)
0.00       FD model depth (km) (0=auto)
0.00       Grid spacing (km) (0=auto)
0          dz multiplier (0=auto)
0.000      Depth where step along z changes (0=auto)
0          Number of absorbing points along x (0=auto)
0          Number of absorbing zones (0=auto)
0          Lowest Q for absorbing zones (0=auto)
```

```
0         Highest Q for absorbing zones (0=auto)
1         Geom. spreading (0=no, 1=yes) for SH (suggested: 0 far/short,1 near/long)
1         Geom. spreading (0=no, 1=yes) for P-SV (suggested: 1)
0        Time window length (s) for 1D SH (0=auto)
0        Time window length (s) for 1D P-SV (0=auto)
0        Time window length (s) for 2D SH (0=auto)
0        Time window length (s) for 2D P-SV (0=auto)
00        Shift in origin time (SH)
00        Shift in origin time (P-SV)
----------------------------------------------------------------------------
Seismograms
----------------------------------------------------------------------------
0         model origin-first calculated seismogram distance (*) (0=auto)
0         Grid points between seismograms (0=auto)
----------------------------------------------------------------------------
cntl files and scripts
----------------------------------------------------------------------------
1         write cntl files (1=yes, 0=no)
1         write script files (1=yes, 0=no)
----------------------------------------------------------------------------
programs used (in order: syl, syr, sylvdv, syndv, finit, finray)
----------------------------------------------------------------------------
syl0048.out
syr0048.out
sylvdv57.out
syndv70.out
finit56b.out
finray53b.out
fdsplit.out
araym81.out
----------------------------------------------------------------------------
running 2D jobs by remote access, reports send to users
----------------------------------------------------------------------------
name@host                               address to send execution reports
/bin/mail                               complete address of program "mail"
----------------------------------------------------------------------------
```

Steps:

The 2D synthetic seismograms calculation has 3 initial steps:

1) To edit file pfdg9.par to describe the modelling:

- The model size cannot exceed the dimensions specified (4000 x 600 along x and z respectively)
- Define all the parameters relative to the modal summation part
- To begin with, let all the parameter relative to the finite differences model be 0. Program pfdg9m.out will try to guess a reasonable choice for all of them. After running pfdg9m.out you'll have to check the choices made by it, and fix those parameters that doesn't fit your needs (usually, shorten the proposed duration of the time series and adjust the treatment of geometrical spreading, or force a different grid step and/or grid multiplying factor).
- In this file you have to put your e-mail address for receiving information when you process your data using LSF system at ICTP

2) To run program **pfdg9m.out**

This program prepares all the scripts and input files required to generate the synthetic seismograms, extracting ground motion from them and plotting typical graphics.

3) To check the output on screen and pfdg9.pri file; to adjust the parameters in pfdg9.par and to repeat step 1 until you're satisfied with the model definition.

These are the files generated by pfdg9m.out:

pfdg9.pri	output writings from pfdg9m.out
*.f2l.VEL.xyz	file with Vs distribution of the model on the FD grid (equal to *.f2r.VEL.xyz)-used for plotting
*.f2r.VEL.cpt	colour palette to plot the velocity model (equal to *.f2l.VEL.cpt)-used for plotting

.par	input parameter files for simple processing of seismograms and plotting
*.bol	.box file for syl to compare with FD SH 1D
*.bor	.box file for syr to compare with FD P-SV 1D
*.f1l	FD model for FD SH 1D
*.f1r	FD model for FD P-SV 1D
*.f2l	FD model for FD SH 2D
*.f2r	FD model for FD P-SV 2D
*.sl1	input file for sylvdv (first column of seismograms)2D SH
*.sl2	input file for sylvdv (second column of seismograms)2D SH
*.sr1	input file for syndv (first column of seismograms) 2D P-SV
*.sr2	input file for syndv (second column of seismograms)2D P-SV
finit.cntl1	.cntl file for FD SH computations (1D)
finit.cntl2	.cntl file for FD SH computations (2D)
finray.cntl1	.cntl file for FD P-SV computations (1D)
finray.cntl2	.cntl file for FD P-SV computations (2D)
rcheck.par	parameter file to run rcheckm1.out that will calculate amplifications
syl.cntl	.cntl file for syl (MS) to compare with FD SH 1D
sylvdv.cntl1	.cntl file for sylvdv (first column of seismograms)SH
sylvdv.cntl2	.cntl file for sylvdv (second column of seismograms)SH
syndv.cntl1	.cntl file for sylvndv (first column of seismograms)P-SV
syndv.cntl2	.cntl file for sylvndv (second column of seismograms)P-SV
syr.cntl	.cntl file for syr (MS)to compare with FD P-SV 1D
jobl	script to run SH computations (syl, sylvdv, finit) 1D and 2D in your working directory
jobr	script to run P-SV computations (syl, sylvdv, finit) 1D and 2D in your working directory
job2D,job2D64	script for doing all process by LSF system at ICTP (see below)
job2Da,job2D64a	script for doing the process considering that SH waves synthetic seismograms are already calculated by LSF system at ICTP
job2Db,job2D64b	script for doing the process considering that both SH and P-SV waves synthetic seismograms are already calculated by LSF system at ICTP
job2Dl,job2D64l	script for calculating only synthetic seismograms of SH waves by LSF system at ICTP
job2Dr,job2D64r	script for calculating only synthetic seismograms of SH waves by LSF system at ICTP
job2Diden,job2D64iden	script for calculating only the 1D part for making the identity test.
job2Dcont,job2D64cont	script for finishing the calculations, once the 1D test is accepted, starting from the same directory
job2DPC	script for performing all the calculations locally in a PC
job2DPCiden,job2DPCcont	equivalent jobs for running in a PC the 1D and 2D parts
job2DPC.1,job2DPC.2	Scripts for doing the 1D and 2D calculations simultaneously. The ".2" script should be started with some delay for avoiding the ".1" script to create working directory and to copy files.
job2DPCiden.1,job2DPCiden.2	Scripts for doing the calculations in the case of 1D on a PC
job2DPCiden.1,job2DPCiden.2	Scripts for doing the calculations in the case of 2D on a PC

Notes

- In bold the most important files
- and asterisk at the beginning means executable file
- Run **pfdg9m.out** more than once, adjusting the parameters and checking the output on screen and pfdg9.pri file until a proper model is obtained

3) To check the model run the Perl script:

```
fdplotm.pl
```

A postscript file named profile_name.model.1.ps will be generated

Calculations on-line in the working directory

1) Run the scripts **jobl** and **jobr** to generate the synthetic seismograms for both Love and Rayleigh waves:

```
sh jobl &
sh jobr &
```

2) Run the program **rcheckm1.out.** It computes spectral amplifications, prepares input files for plotting diverse graphics and calculates some single valued ratios 2D/1D of ground motion parameters. It also writes input files for programs "pcondfd", "newplots1" and some ".rat" files with real data of ratios 2D/1D of ground motion parameters for program "tab_cor".

Parameter files for plotting (generated pfdg9m and rcheckm1)

fdplota.par.hv1df	parameter file to plot H/V for 1D FD (for 1D test)
fdplota.par.hv1dm	parameter file to plot H/V for 1D MS (for 1D test)
fdplota.par.hva2d	parameter file to plot H/V for SA 2D
fdplota.par.hvd2d	parameter file to plot H/V for SD 2D
fdplota.par.hvpv2d	parameter file to plot H/V for PSV 2D
fdplota.par.hvv2d	parameter file to plot H/V for SV 2D
fdplota.par.rsp1df	parameter file to plot the RS for 1D FD (for 1D test)
fdplota.par.rsp1dm	parameter file to plot the RS for 1D MS (for 1Dtest)
fdplota.par.rsp2d	parameter file to plot RS for SA
fdplota.par.rsr1d	parameter file to plot the RSR for SA for 1D test
fdplota.par.rsra2d	parameter file to plot the RSR for SA
fdplota.par.rsrd2d	parameter file to plot the RSR for SD
fdplota.par.rsrpv2d	parameter file to plot the RSR for PSV
fdplota.par.rsrv2d	parameter file to plot the RSR for SV
fdplotm.par	parameter file to plot the FD model
plots1dL.par	parameter file to plot the transverse displacement for 1D test
plots1dR.par	parameter file to plot the radial velocity for 1D test
plots1dZ.par	parameter file to plot the vertical velocity for 1D test
plots2dL.par	parameter file to plot the transverse components for the 2D model
plots2dR.par	parameter file to plot the radial components for the 2D model
plots2dZ.par	parameter file to plot the vertical components for the 2D model
fdplota.par.hva2d1d	parameter file to plot the 2D/1D ratio of the RSP quotient H/V for acceleration
fdplota.par.hvv2d1d	parameter file to plot the 2D/1D ratio of the RSP quotient H/V for velocity
fdplota.par.hvd2d1d	parameter file to plot the 2D/1D ratio of the RSP quotient H/V for displacement
fdplota.par.hvpv2d1d	parameter file to plot the 2D/1D ratio of the RSP quotient H/V for pseudo velocity

3) Run program **pcondfd.out** that calculates of the energy input ratio, writes the input files for plotting it, and prepares some input files for program "newplots1".

Input file for program "pcondfd":

```
pcond.par
```

It is written by program rcheckm1

Parameter files for plotting:

```
fdplota.par.eir        parameter file to plot EI ratio
fdplota.par.eir_lg     parameter file to plot EI ratio (log)
```

4) Run program **newplots1.out**. It reads the ground?.inp files, writes a set of input files for plotting ground motion parameters along profile and some ".rat" files with real data of ratios 2D/1D of ground motion parameters.

Input files for program "newplots1":

ground1.inp	A matrix containing the data about maximum ground motion and Arias intensities for the 3 components and both 1D and 2D seismogram (generated by pcondfd.out)
ground2.inp	A list of files with data about energy input ratio (generated by pcondfd.out)
ground3.inp	A list of files with data about response spectra (generated by rcheckm1.out)
ground4.inp	A simple file with epicentral distance to each receiver in the two cases: (tra,rad) and ver (generated by rcheckm1.out)
ground5.inp	A list of files wih data about response spectra ratio (generated by rcheckm1.out)
ground6.inp	A list of files with data about energy input ratio maxima (generated by pcondfd.out)
ground7.inp	A table with data about ratio 2D/1D of response spectra quotient H/V (generated by rcheckm1.out)

Parameter files for plotting created by newplots1:

fdplotxy.acrsmaxrad(tra,ver)	Acceleration response spectra maximum 1D and 2D (amplitude and period). 1 graphic by component
fdplotxy.versmaxrad(tra,ver)	Velocity response spectra maximum 1D and 2D (amplitude and period). 1 graphic by component
fdplotxy.dirsmaxrad(tra,ver)	Displacement response spectra maximum 1D and 2D (amplitude and period). 1 graphic by component
fdplotxy.aeir(dmaxr,vmaxr,amaxr,epar,iariasr,,eirmax,lg_eirmax)	Ratio 2D/1D of area under energy input (dmax, vmax, amax, effective peak acceleration, Arias intensity, maximum of energy input, logarithm of energy input). The 3 components together
fdplotxy.eimaxrad(tra,ver)	Maximum of energy input 1D and 2D (amplitude and period). 1 graphic by component
fdplotxy.psvrsmaxrad(tra,ver)	Pseudo velocity response spectra maximum 1D and 2D (amplitude and period). 1 graphic by component
fdplotxy.rsrAmax(Dmax,PSVmax,Vmax)	Maximum of response spectra ratio for acceleration (displacement, pseudo velocity, velocity). The 3 components together

Files with data to be plotted (see in fdplotxy. files the corresponding to each graphic)*

```
.aeiratio.rac(tac,zac), .amaxratio.rac(tac,zac),
    .dmaxratio.rdi(tdi,zdi), .epamaxratio.rac(tac,zac),
    .iariasratio.rac(tac,zac), .vmaxratio.rve(tve,zve)
.Ars1D.rac(tac,zac),    .Ars2D.rac(tac,zac),
    .eimax1D.rac(tac,zac),     .eimax2D.rac(tac,zac), .eirmax.rac(tac,zac),
    .lg_eirmax.rac(tac,zac), .rsrAmax.rac(tac,zac),
    .rsrDmax.rac(tac,zac), .rsrPSVmax.rac(tac,zac), .rsrVmax.rac(tac,zac)
.Drs1D.rdi(tdi,zdi), .Drs2D.rdi(tdi,zdi)
.PSVrs1D.rpsv(tpsv,zpsv), .PSVrs2D.rpsv(tpsv,zpsv)
```

```
.tmaxArs1D.rac(tac,zac), .tmaxArs2D.rac(tac,zac),
   .tmaxDrs1D.rdi(tdi,zdi), .tmaxDrs2D.rdi(tdi,zdi), tmaxei1D.rac(tac,zac),
   .tmaxei2D.rac(tac,zac), .tmaxeir.rac(tac,zac),.tmaxlg_eir.rac(tac,zac),
   .tmaxPSVrs1D.rpsv(tpsv,zpsv),.tmaxPSVrs2D.rpsv(tpsv,zpsv),.tmaxrsrA.rac(
   tac,zac),
   .tmaxrsrD.rac(tac,zac),.tmaxrsrPSV.rac(tac,zac),.tmaxrsrV.rac(tac,zac),.
   tmaxVrs1D.rve(tve,zve), .tmaxVrs2D.rve(tve,zve)
.Vrs1D.rve(tve,zve), .Vrs2D.rve(tve,zve)
.rva2d1d,.tva2d1d,.hva2d1d,.rvv2d1d,.tvv2d1d, .hvv2d1d, .rvd2d1d, .tvd2d1d,
    .hvd2d1d, .rvpv2d1d, .tvpv2d1d, .hvpv2d1d
```

8) Run program **tab_cor.out** to make a correlation analysis between several ground motion ratio 2D/1D variables

Input to tab_cor:

File tabcor.inp and several files .rat created by programs rcheck1 and newplots1

Output of tab_cor:

One file n_o_m.cor with the correlation analysis

9) Run program **escenario.out** to select information of a 2D earthquake scenario. It uses as input several files "*.rat" created by previous programs and write results in the file n_o_m.esce.

10) Plot what has been generated (seismograms, amplifications, etc.)

```
sh plotall
```

11) Revise the plots with gs or gv or to print them for posterior revision using

```
sh printall
```

Computation of synthetic seismograms by remote access

The 2D process cans late for many ours, and it is necessary to do it by using the ICTP rules for long jobs. In this case, the process should be executed in a batch queue, and you can't control the different parts as was described above. The program "pfdg9m" also creates a script named job2D with all the needed command line instructions, that guides the process from data preparation to results storage, including notification by e-mail of the process advance. As the calculation of synthetic seismograms and graphics preparation requires a huge amount of disk storage space, the process is run out of your home partition in ICTP, and the obtained graphs (and the other results) are put in files compressed with programs " bzip2" and "zip" that can be easily decompressed in any Linux platform; bzi2 program was selected for bigger files because the compressed files are sensibly shorter than the obtained with other programs (some Windows programs can decompress them also – e.g., the free Izarc or 7-zip). They are placed back in your home partition and should be transferred for their posterior analysis at home institutions and for writing reports or papers.

The new "**pfdg9m.out**" program creates several executable files. **job2D** executes all the operations described in the previous section (except printing of graphs), informing you by email how your calculations are going. It will send 4 messages by email: "jobl finished" with a listing of the execution time of the programs of SH waves synthetic seismograms calculations, "jobr finished" with an equivalent content for P-SV waves, "profile name_of_file_pof calculated, see file ps2D.tar.bz2" with a listing of the prepared graphs and "copy and delete results from your_working_directory" with the list of compressed files copied there. ***Note:*** In last time these messages are not being sent because of changes in the system at ICTP .

The way of running long jobs in ICTP is the "batch queue system" (LSF). This is not a very simple procedure. The LSF system installed on ICTP computer network, consist of several machines to which you don't have direct access. The system automatically send your job to one of them, which makes the calculations. By the other hand, our FD calculations may be very long and they may exceed the time allowed for normal jobs (10 hours). It may arise for big profiles (longer than about 10Km). In order to guarantee the best performance of LSF running is necessary to do:

newgrp lsf

this will change your working group to the group of users that has access to the queue "week", that means that your job can last for 1 week. The inclusion of a user in the group "lsf" is done by special request to Scientific Computer Section (SCS) of ICTP. The process of sending a job to LSF continues as:

```
lsfrun bhosts
```

and you will obtain a list of the active machines. Select one of them (analyse the statistics on your screen and be sure that the selected machine is working and have not many processes running simultaneously). The selection of the hostname is very important because unfortunately lsfrun sometimes doesn't work very well and your job is sent to a non working machine. Then issue the command

```
lsfrun  bsub -m HOSTNAME -q week job2D
```

where HOSTNAME is the name that you selected from the list. Instead of "job2D", you can put "job2Da", "job2Db", "job2Dl" or "job2Dr".

For checking if your job is running or waiting, you can issue the command

```
lsfrun bjobs
```

If for any reason you want to cancel your job, look for the number that is assigned to it in "lsfrun bjobs" reponse and issue the command

```
lsfrun bkill number_of_your_job
```

Important note:

If you want to know more about the "batch queue system" that is used for running your 2D calculation process, see http://scs.ictp.it/ictpguide/lsf/

Running long jobs in the computer amd64-sand of the SAND group of ICTP

Due to limitations in the LSF system (both in capacity and speed of calculations) for us it was authorized the access to the high speed 64 bits computer "amd64-sand" belonging to SAND group of ICTP. This computer is not accessible from LSF system, and a different procedure has to be applied. For this reason, program "pfdg9m" has been modified and now in a run you will obtain additionally the files (job2D64, job2Da64, job2Db64, job2Dl64, job2Dr64). They do the same process of the old (job2D, job2Da, job2Db, job2Dl, job2Dr), using as working directory the /scratch in the "amd64-sand" computer, instead of the "/home/nfs3" that was used by LSF runs.

First of all, you have to enter in ICTP computer network by ssh:

```
ssh  your_login_at_ICTP@ssh1.ictp.it
```

(also ssh.ictp.it or ssh2.ictp.it)

As the access to the "amd64-sand" computer is limited to group "geophys", all of us have now the group "geophys" as a secondary group. You can verified this with the command:

```
id  your_login_name
```

then, for working in this machine, you have to put temporally this group as primary, which is done with the command:

```
newgrp  geophys
```

After this you have to log in "amd64-sand" computer, which is done by:

```
ssh  amd64-sand
```

Once logged in, your job is sent to background execution through:

```
nohup   ./job2D64   ...   &
```

and the program is in execution. Now you can control the process by the command:

```
ps  ux
```

that will indicate not only the time spent since the beginning of job2D64, but the consecutive running of all the programs called by this script.

Your job will be running in the working directory
/scratch/SMLAC-name_e_mail_in_pfdg9.par,
where "name_e_mail_in_pfdg9.par" is the user part of the e_mail that you give in your "pfdg9.par" file, which is deleted once the process is completed. If you want to run several profiles at the same time, put different e-mail directions in each one, even if these directions do no exist.

Running our jobs in this computer has the advantages:

- the programs run much faster
- the /scratch directory has enough space for our work
- the computer normally is not overcharged of work

How the job2D works

a) In the file "pfdg9.par" you give the e-mail address for sending you the email reports. These address can be modified, and even you can put a non existing e-mail. Program "pfdg9m" only requires that it has a "name@host" format. It creates with this address a name of a working directory "SMLAC-name". The scrip job2D creates this directory at the scratch directory /home/nfs3/. Then, the absolute address of your working directory will be "/home/nfs3/SMLAC-name", and you can check then how your job is running. If at the beginning of your job this directory exist, it will be deleted. It is important to take into account that, if you want to sent to run several scripts job2D, in each one you have to put a different e-mail address.

b) All the files that are in your initial directory are copied to "/home/nfs3/SMLAC-name" and then they are compressed in your initial directory under a name "n_o_m.initial_data.zip". The control is transferred to the working directory "/home/nfs3/SMLAC-name" where calculations are done.

c) When the calculation of synthetic seismograms for SH waves finished, there are copied to the initial directory the results plus the corresponding .pri files with indication about run of programs "syl", "sylvdv" and "finit". The files transferred are "n_o_m.l1d.bz2", "n_o_m.l2d.bz2". "n_o_m.syl.bz2" and "n_o_m.snapshots_L.tar.bz2".

c) When the calculation of synthetic seismograms for P-SV waves finished, there are copied to the initial directory the results plus the corresponding .pri files with indication about run of programs "syr", "syndv" and "finray". The files transferred are "n_o_m.r1d.bz2", "n_o_m.r2d.bz2". "n_o_m.syr.bz2" and "n_o_m.snapshots_R.tar.bz2".

d) The last process is the extraction of ground motion data and graphics plotting. After conclusion there are copied to the initial directory the files "n_o_m.ps2D.tar.bz2", "n_o_m.pri.tar.bz2", "n_o_m.p.extra.tar.bz2", "n_o_m.correl.zip" and "n_o_m..dat_P4.zip"

e) The working directory "/home/nfs3/SMLAC-name" is deleted.

For doing the process you need:

- to create a new directory, that cans be inside the 1D one (is not recommendable to work in the same directory used for 1D calculations, because during execution all files are compressed in a single one); the directory structure more convenient is when it is used an independent directory for each profile)
- to copy in this directory the files "n_o_s.spl" and "n_o_s.spr" obtained in the 1D

calculations

- to copy in this directory the files "pfdg9.par" with the specifications for the finite differences model and "n_o_p.pof" with the description of the profile, that you have to prepare before
- to execute " **pfdg9m.out**" the times it will be necessary until you have properly adjusted all the parameters
- send job2D to LSF queue processing (see above explanation). If you run directly the script job2D, the machine will process your data, but if any of the programs called by the script remains more than 15 minutes in execution, the system will cancel it and you will not obtain good results by the whole process.
- to check in your initial directory if partial results are been saved; at the end of the job you should have 14 compressed files plus several execution reports "*.pri" files; additionally you should receive the email notifications about the execution of the different steps of "job2D" to the e-mail address given by you in the pfdg9.par file, and an additional message to your ICTP account with a summary of the complete execution (the display messages plus lsf run statistics), but it doesn't work always
- if the process finished satisfactorily, to transfer the graphics, that appears in "n_o_m.ps2D.tar.bz2"
- to analyse them; first to check the seismograms, second, to check the identity test (see below), and then, if you are satisfied with the obtained results, to transfer and save the other compressed files
- if you detected some problems in your results, to run again the whole process, making the necessary changes in file pfdg9.par

Take into account the volume of generated files, that for a profile of about 10 km length may be around 50 MB of compressed information --> transfer them for analysis on your PC

WARNINGS:

The possibility of running the hole process by using only some instructions do not means that you don't need to made some checking before the major calculations. In particular, you have to revise carefully the output messages on screen of program `"pfdg9m.out"`*, and make by hand in its input file* `"pfdg9.par"` *the necessary adjustments.*

Before considering that you have your final results you have to be sure that your data passed satisfactorily the identity test (see below). Perhaps you will need to run again your 2D job more than once.

How the job2Da, job2Db, job2Dl and job2Dr work

The scripts "job2Da" and "job2Db" do part of the work done by job2D. They are used when LSF system is not working properly and job2D cancels before finishing. "job2Da" is used when job2D was cancelled after the SH waves synthetic seismograms had been calculated and "job2Db" is used when job2D was cancelled after the P-SV waves synthetic seismograms had been calculated. If you are in one of this cases you have to decompress in your initial directory the file "n_o_m.initial_data.zip" and run by LSF the corresponding script. Be sure that in this directory are present the compressed files with synthetic seismograms already calculated. The script creates a working directory /home/nfs3/SMLAC-name in the scratch disk (home/nfs3) in the same way that "job2D" does. Then, it copies all the files in the working directory, decompress the synthetic seismograms files and continues the process as "job2D" does.

The scripts "job2Dl" and "job2Dr" are used for calculating only the synthetic seismograms of SH and P-SV respectively. They are executed in the same way that "job2D"

Graphics generated in a complete run of the 2D calculations

.hv1df.1.ps	relations T/V, RV and H/V for 1D FD 5% damping – displacement [f(ω,x)]
.hv1dm.1.ps	relations T/V, RV and H/V for 1D FD at 5% damping – displacement [f(ω,x)]
.hva2d.1.ps	relations T/V, RV and H/V for 2D at 5% damping – acceleration [f(ω,x)]
.hvd2d.1.ps	relations T/V, RV and H/V for 2D at 5% damping – displacement [f(ω,x)]
.hvpv2d.1.ps	relations T/V, RV and H/V for 2D at 5% damping – pseudo velocity [f(ω,x)]
.hvv2d.1.ps	relations T/V, RV and H/V for 2D at 5% damping – velocity [f(ω,x)]
.plots1dL.1.ps	seismograms 1D transverse displacement, upper plot MS, lower plot FD 1D
.plots1dR.1.ps	seismograms 1D radial velocity, upper plot MS, lower plot FD 1D
.plots1dZ.1.ps	seismograms 1D vertical velocity, upper plot MS, lower plot FD 1D
.plots2dL.1.ps	seismograms 2D transverse displacement, velocity and acceleration
.plots2dR.1.ps	seismograms 2D radial displacement, velocity and acceleration
.plots2dZ.1.ps	seismograms 2D vertical displacement, velocity and acceleration
.rsp1df.1.ps	response spectra 1D FD transverse, vertical and radial at 5% damping [f(ω,x)]
.rsp1dm.1.ps	response spectra 1D MS transverse, vertical and radial at 5% damping [f(ω,x)]
.rsp2d.1.ps	response spectra 2D transverse, vertical and radial at 5% damping [f(ω,x)]
.rsr1d.1.ps	response spectra ratio MS/1D_FD transverse, vertical and radial at 5% damping [f(ω,x)]
.rsra2d.1.ps	response spectra ratio 2D/1D_FD transverse,vertical and radial at 5% damping for acceleration (SA) [f(ω,x)]
.rsrd2d.1.ps	response spectra ratio 2D/1D_FD transverse,vertical and radial at 5% damping for displacement (SD) [f(ω,x)]
.rsrpv2d.1.ps	response spectra ratio 2D/1D_FD transverse,vertical and radial at 5% damping for pseudo velocity (PSV)[f(ω,x)]
.rsrv2d.1.ps	response spectra ratio 2D/1D_FD transverse,vertical and radial at 5% damping for velocity (SV) [f(ω,x)]
.test1dr.peak.ps	amax percent difference 1D_FD/MS – classic 1D test, radial velocity scaled for magnitude
.test1dr.upeak.ps	maximum amplitude original unscaled unfiltered percent difference 1D_FD/MS for radial velocity
.test1dt.peak.ps	amax percent difference 1D_FD/MS - classic 1D test, transverse displacement scaled for magnitude
.test1dt.upeak.ps	maximum amplitude original unscaled unfiltered percent difference 1D_FD/MS for transverse displacement
.test1dz.peak.ps	amax percent difference 1D_FD/MS - classic 1D test, vertical velocity scaled for magnitude
.test1dz.upeak.ps	maximum amplitude original unscaled unfiltered percent difference 1D_FD/MS for vertival velocity
f0.eir.1.ps	energy input spectra ratio [f(ω,x)]

f0.lg_eir.1.ps	energy input spectra ratio [f(ω,x)] (logarithmic scale)
.aeir.fdplota.1.ps	area under energy input spectra ratio 2D/1D [f(x)]
.amaxr.fdplota.1.ps	maximum acceleration ratio 2D/1D [f(x)]
.dmaxr.fdplota.1.ps	maximum displacement ratio 2D/1D [f(x)]
.vmaxr.fdplota.1.ps	maximum velocity ratio 2D/1D [f(x)]
.epar.fdplota.1.ps	effective peak acceleration ratio 2D/1D [f(x)]
.iariasr.fdplota.1.ps	Arias intensity ratio 2D/1D [f(x)]
.eirmax.fdplota.1.ps	maximum energy input spectra ratio 2D/1D, all components {T(x),f(x)}
.lg_eirmax.fdplota.1.ps	maximum energy input spectra ratio 2D/1D, all components {T(x),f(x)} (logarithmic scale)
.rsrAmax.fdplota.1.ps	maximum acceleration response spectra ratio 2D/1D, all components {T(x),f(x)}
.rsrDmax.fdplota.1.ps	maximum displacement response spectra ratio 2D/1D, all components {T(x),f(x)}
.rsrPSVmax.fdplota.1.ps	maximum pseudo velocity response spectra ratio 2D/1D, all components {T(x),f(x)}
.rsrVmax.fdplota.1.ps	maximum velocity response spectra ratio 2D/1D, all components {T(x),f(x)}
.acrsmaxrad.fdplota.1.ps	acceleration response spectra maximum for radial component, 2D and 1D {T(x),f(x)}
.acrsmaxtra.fdplota.1.ps	acceleration response spectra maximum for transverse component, 2D and 1D {T(x),f(x)}
.acrsmaxver.fdplota.1.ps	acceleration response spectra maximum for vertical component, 2D and 1D {T(x),f(x)}
.dirsmaxrad.fdplota.1.ps	displacement response spectra maximum for radial component, 2D and 1D {T(x),f(x)}
.dirsmaxtra.fdplota.1.ps	displacement response spectra maximum for transverse component, 2D and 1D {T(x),f(x)}
.dirsmaxver.fdplota.1.ps	vertical response spectra maximum for transverse component, 2D and 1D {T(x),f(x)}
.psvrsmaxrad.fdplota.1.ps	pseudo velocity response spectra maximum for radial component, 2D and 1D {T(x),f(x)}
.psvrsmaxtra.fdplota.1.ps	pseudo velocity response spectra maximum for transverse component, 2D and 1D {T(x),f(x)}
.psvrsmaxver.fdplota.1.ps	pseudo velocity response spectra maximum for vertical component, 2D and 1D {T(x),f(x)}
.versmaxrad.fdplota.1.ps	velocity response spectra maximum for radial component, 2D and 1D {T(x),f(x)}
.versmaxtra.fdplota.1.ps	velocity response spectra maximum for transverse component, 2D and 1D {T(x),f(x)}
.versmaxver.fdplota.1.ps	velocity response spectra maximum for vertical component, 2D and 1D {T(x),f(x)}
.eimaxrad.fdplota.1.ps	energy input maximum for radial component, 2D and 1D {T(x),f(x)}
.eimaxtra.fdplota.1.ps	energy input maximum for transverse component, 2D and 1D {T(x),f(x)}
.eimaxver.fdplota.1.ps	energy input maximum for vertical component, 2D and 1D {T(x),f(x)}
.model.1.ps	1 page plot of the model alone
.hva2d1d.1.ps	2D/1D ratio of the RSP quotient H/V for acceleration
.hvv2d1d.1.ps	2D/1D ratio of the RSP quotient H/V for velocity
.hvd2d1d.1.ps	2D/1D ratio of the RSP quotient H/V for displacement
.hvpv2d1d.1.ps	2D/1D ratio of the RSP quotient H/V for pseudo velocity

All the names begin with “n_o_m”

Content of the files placed in your working directory after a LSF run

.initial_data.zip	content of the directory after running pfdg9m.out
.extra.tar.bz2	intermediate input files with information extracted from synthetic seismograms
.l1d.bz2	1D Love waves FD seismograms
.l2d.bz2	2D Love waves FD seismograms
.pri.tar.bz2	files .pri issued by the different programs
.ps2D.tar.bz2	the graphics in PostScript format
.r1d.bz2	1D Rayleigh waves FD seismograms
.r2d.bz2	2D Rayleigh waves FD seismograms
.snapshots_L.tar.bz2	snapshots of the different FD runs (1D and 2D, Love waves
.snapshots_R.tar.bz2	snapshots of the different FD runs (1D and 2D, Rayleigh waves
.syl.bz2	Love waves MS seismograms
.syr.bz2	Rayleigh waves MS seismograms
.correl.zip	input data and results of correlation analysis between single valued ratios 2D/1D of selected ground motion parameters plus a file with 2D scenario data
.dat_p4.zip	selected functions GM(f) along profiles to be processed for using program p4 for classification

All the names begin with "n_o_m"

The identity test in hybrid (MS+FD) calculations

The correct use of a FD scheme requires that you make a test on "identity" of results. This test consist in the calculation of synthetic seismograms in the surface both by modal summation analytical procedure for the regional model at points in the region in which the 2D model will be embedded, and the same calculation using the hybrid technique, when the 2D embedded model is identical to the regional model. The objective of this is to guarantee that the FD numerical procedure do not introduce numerical errors in the calculated seismograms for the 2D model. This is done automatically by the script that you run (job2D of the procedure described in this manual) and you obtain 9 graphics to control the results of the test:

a) `n_o_m.plots1dL.1.ps`, `n_o_m.plots1dR.1.ps` and `n_o_m.plots1dZ.1.ps` with the composite plot model + seismograms FD1D + seismograms MS for transverse displacement, radial velocity and vertical velocity
b) `n_o_m.test1dr.peak.ps`, `n_o_m.test1dt.peak.ps` and `n_o_m.test1dz.peak.ps` with amax percent difference 1D_FD/MS – classic 1D test for radial velocity, vertical velocity and transverse displacement scaled for magnitude
c) `n_o_m.test1dr.upeak.ps`, `n_o_m.test1dt.upeak.ps` and `n_o_m.test1dz.upeak.ps` with maximum amplitude original unscaled unfiltered percent difference 1D_FD/MS for radial velocity, vertical velocity and transverse displacement.

There is a difference in the input ground motion for making the test in Love and Rayleigh waves. Love waves uses displacement and Rayleigh waves velocity. This is doubt to the fact that the input data for the programs of the FD scheme (the 2 columns of seismograms at the beginning of the profile) correspond to displacement for Love waves and to velocity for Rayleigh waves (this is a characteristic of the computer codes). Then, the identity of outputs have to be seek avoiding the use of signals that have passed a process of numerical integration or derivation.

The visual inspection of the graphics "n_o_m.plots1dL.1.ps", "n_o_m.plots1dR.1.ps" and "n_o_m.p.plots1dZ.1.ps" should evidence the cases in which the waveforms are different.

This is not common, but should occur. The other graphics show the maximum difference in amplitude of the signals between the MS and FD1D cases. From the experience of SAND group, a value greater than 6% is not acceptable in these plots. There are another 5 files that can give an idea about how close are the 1D MS and the 1D FD calculations. The first two correspond to simple response spectra (5% damping) for acceleration calculated for 1D MS and 1D FD seismograms (n_o_m.rsp1dm.1.ps, n_o_m.rsp1df.1.ps), while other two correspond to the response spectra (5% damping) for acceleration quotients (T/V, R/V and H/V) calculated for 1D MS and 1D FD seismograms (n_o_m.hv1dm.1.ps, n_o_m.hv1df.1.ps). In both cases the graphics should looks very similar between them. The other file corresponds to response spectra ratio MS/(FD 1D) calculated also with 5% damping for acceleration (n_o_m.rsr1df.ps). It should reflect values close to 1.

Running simultaneously several profiles

Warning!!! In Linux you can run simultaneously several times the same program, but when a process creates and delete directories you have to take special care in preparing those runs. Two things have to be taken into account:

1) Prepare the run of each profile in a separate directory. The jobs delete initial contain of this directory when passing to run in the working directory.
2) Use a different e-mail addresses for message sending (line 71 of "pfdg9.par"). The name of the running directory will be formed by the characters until the "@"; i.e., if you put the address "cmendoza@ictp.it" your job will be executed in the working directory "scratch/SMLAC-cmendoza". If you repeat the e-mail address in all the cases, sending second profiles will cancellate the files of previous one and so on, and at the end you will obtain wrong results or no results at all.

Saving time in making identity test

For the identity they are used only the 1D calculations, i.e., the ".syl-.syr" files generated by programs "syl0048" and "syr0048", and the ".l1d-.l1r" generated by programs "finit56" and "finray53". The files ".l2d-.l2r" are not used in this test, and calculating them takes a lot of time (the total duration of the process is almost twice the duration when only 1D calculations are done). It is convenient to use the scripts "job2Diden" or "job2D64iden" for making the identity test calculations alone. The result will contain the corresponding seismograms and a limited quantity of graphs; between them, the ones that you need for checking the 1D test. When it finish, in your working directory you will find the same files that in a normal job2D or job2D64 run with the exception of "profile.correl.zip", "profile.dat_P4.zip" and "profile.extra.tar.bz2".

Check the graphs contained in "profile.ps2D.tar.bz2". If you are satisfied run the script "job2Dcont" or "job2D64cont" for finishing your task. If not, uncompress the file "profile.initial_data.zip", modify the pfdg9.par and rerun "pfdg9m.out" and then "job2Diden" or "job2D64iden" as corresponds.

Running the "*iden" scripts will reduce to almost a half the time for making the identity test. By continuing, once accepted the test, with corresponding "*cont" scripts, will reduce also to almost a half the time for completing your task.

Running in PC

If you are working in a PC that have access to the necessary programs you can use the the scripts named “2DPC” instead of sending the jobs to LSF system or to amd64-sand machine. In that case, if your PC is of high performance (processor “X2 or X4” in AMD or “Duo or Quad” in Intel) you can use the variants of the scripts “.1” and “.2” and save considerable time (about 30%) by running them in parallel. Use two terminal windows. For do it, in one terminal, you have to start first the “.1” script, that will create the working directory, copy then files (and uncompressing them if necessary), and finally pass to 1D calculations. In the second terminal control that this part is already running (by issuing “ps ux” you should see that one of the programs syl, sylvdv or finit have started) and then start the “.2” part.

What to do in the case in which you obtain wrong results?

1) Program pfdg9m fails

Sometimes, when you run npfdg9m, you don't obtain a normal result, in the screen you see the message “STOP 25 statement executed” and in pfdg9.pri file appears the message “program interrupted ! the change of gridspacing (nfb) should be in a homogeneous region”. It is due to the fact that the change of depth interval between receivers in the column (they should be placed more closest between them until the depth of the 2D model) occurs on an interface of the 1D model. You can solve the problem by putting a depth not coinciding with interfaces of the 1D model in the line 34 of the pfdg9.par file: “Depth where step along z changes (0=auto)”

2)You do not obtain the 60 graphics

If your file n_o_m.ps2.tar.bz2 do not contain the expected 60 graphics, it means that one or more programs failed. The first action is to revise the message that the LSF system have to be sent to you. Then you will be able to discriminate if it was a system error or a program error. In the first case resend your job. In the last case, you should analyse the outputs messages of each program (*.pri) that are in the file n_o_m.pri.tar.bz2, following the order in which they are called in “jod2D”. Once determined which programs failed, you should modified the particular data passed as input for them in file pfdg9.par.

3)The 1D test is rejected

In case of rejection of 1D identity test you have to turn back to the pfdg9.par file where you fix the parameters of the FD calculations. It is assumed that you have carefully checked the 1D part of the process, and the Love and Rayleigh spectra that your using are right. There are several points that you may control:

- The use of geometrical spreading (lines 39 and 40 of pfdg9.par file) may have a big influence on amplitudes. Putting 0 or 1 in both of them you will obtain different results. If the graph of “peak” or “upeak” type shows a high increase from left to right, probably it means that for this wave you didn't use the geometrical spreading and it is necessary to put it in calculations. By the other hand, if you see a high decrease in that plots from left to right it probably means that for this wave you used the geometrical spreading and it is not necessary to put it in calculations
- The depth of the model (line 31) may be a source of problems. Put a bigger value that the one fixed automatically by program pfdg9m.out.

4) The run of finit56b breaks

Sometimes, in cases of a 2D model not differing so much of the 1D model, you can obtain in pfdg9.pri, if you let all the options controlling model as automatic, a printout of the kind:

```
Sampling along x...................:   0.28300 km
Sampling along z...................:   0.28300 km
Dz change at (km from free surface).:  31.41300 km (nfb(2D)=112, nfb(1D)=112)
Number of layers in reference model.:  83
Multiplying factor for dz (nf)......:   1
Sampling along z below heterogeneity:   0.28300 km
Dimension along x..................: 129.04800 km ( 457 grid points)
Dimension along z..................:  30.56400 km ( 109 grid points)
INFO - NFB is deeper than the model, and will not be used
```

Note that in this case the dimension along Z of the model is less that the depth at which sampling Dz should change. It means that you will create input seismograms columns of equally spaced seismograms of only one block. If you continue, program finit56b will stop by error, because it needs at least two blocks of equally spaced seismograms with different spacing each one (the shallower more closest one to each other). For solving this, fix in the pfdg9.par the parameters:

```
160        FD model depth (km) (0=auto)
0          Grid spacing (km) (0=auto)
2          dz multiplier (0=auto)
81         Depth where step along z changes (0=auto)
```

in which case it is recommended that the “FD model depth” be fixed about twice the depth of the 2D embedded model, and the “Depth where step along z changes” should be fixed close to the maximum depth of the 2D model.

5) Calculation in long profiles fails

Programs finit56 and finray53 exist in several versions. That only differs one from each other in the maximum dimension in time and space that they allow to process. Begin working with finit56a.out and finray53b.out. These versions are less memory consuming and your job will run faster. But sometimes long profiles requieres to use the versions finit56b.out and finray53c.out. You can decide what to use if you control the output of pfdg9m (pfdg9.pri). Put 4000 in the line that controls horizontal distance (line 26, Max number of grid points along X) and check what is the real number of grid points that your profile requieres. If this number is less or equal to 2800 you can use finit56a.out and finray53b.out, but it is greater than this value you should use finit56b.out and finray53c.out (lines 64 and 65 of pfdg9.par).

6) The run of finit56 or finray53 stops with a message “stop 444”

This problem is presented when you are calculating seismograms with long duration. Program pfdg9 normally estimate the seismogram duration in excess. This is not a problem when you are calculating profiles close to the epicenter, but, if you are apart from it, your seismograms will be longer and the times that calculate pfdg9.out are very big. If you pass this information to the job, probably your FD calculations were break with message stop 444, and a explanation about that the progran can calculate so long in time signals (the remainder part of the job will be wrong). You can see that in the .finit1D.pri, .finit2D.pri, .finray1D.pri and .finray2D.pri. First of all, use finit56b.out and finray53c.out (lines 64 and 65 of pfdg9.par). They can manager the longer in time as possible seismograms. Then control how much time you really need (see 2D seismograms) and reduce the time in accordance (lines 41-44 in file pfdg9.par). Check if with this reduced time you cam use programs finit56a.out and finray53b.out.

7) The identity test gives very high values in the case of SH waves

It happens frequently when you have long profiles at long distance of source. Normally is very difficult to adjust parameters for eliminating the problems. If all your efforts fail, try to eliminate high frequencies introducing a low pass filter at about 5 hertz (lines 8-10 of “pfdg9.par” file). In many cases it works; your results will be less general, but unless you have to study very tall buildings, they will be completely satisfactory.

Final recommendations

1. In the pfdg9m.out run check always the output pfdg9.pri. Then you can see what was the time window selected for all seismograms, and the distance between seismograms. You should fix them before passing to synthetic seismograms calculation. The distance between seismograms depends on your needs; do not put shorter distances than you need; you will save time of calculation and volume of resulting files (it is regulated by the option “Grid points between seismograms”) . The automatic option of the pfdg9m program puts very big time windows that sometimes are out of the possibilities of processing by programs finit and finray. You can see the results of your 1D test and take about 20-30 % over the length of the obtained signals.
2. At present we are using versions “finit56b.out” and “finray53b.out” of FD programs (instead of finit56a.out and finray53a.out as was in the initially distributed pfdg9.par files). For this you have to change the corresponding lines at the end of the pfdg9.par file and also to put 4000 instead of 2800 in the “Max number of grid points along x” parameters. Be sure that you are using the right pfdg9.par file.
3. Don't consider good your results unless the identity test have been passed satisfactorily. If with the recommendations of this manual you don't solve the problem, contact Franco Vaccari or Leonardo Alvarez.

8) The identity test gives very high values because of the presence of spurious signals at the end of the seismograms

The solution of this problem is to cut the seismograms before the spurious signals arrive. The "normal" way is to limit the total duration of seismograms and recalculate them. But it takes a lot of computing time. A simple way to solve this problem is to use the program "cortasis" that cuts the time series by the end. It has the input file "cortasis.inp" with the structure:

```
name_of_FD_file
real_duration  desired_duration
    . . .
    . . .
    . . .
```

two lines for ech seismogram file. If you cut the seismogramas using this program you need to replot all the graphics, and you need also to change the parameter files for then. Then it is necesary to rerun pfdg9m program with the new time span of the seismogram - "desired_duration" -, not only for this adjustment but for the calculation of 2D seismograms with the right duration.

You can use program "cortasis" for all the FD seismograms, if you detect the problem after a complete run. Then you adjust all the FD seismograms to the desired duration (the MS ones are always smaller in time duration), put the new adjusted FD seismograms together with MS ones in a working directory, rerun the "pfdg9m" program, and them modified one of the scripts "job2Db" or "job2Db64" for preparing the adjusted plots and the new data for microzoning (files "correl" and "dat_P4" mainly).

Contact persons:

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Leonardo Alvarez (Centro Nacional de Investigaciones Sismológicas, Cuba) – leoalvar@chcenais.cu, leoalvar@ictp.it
Use both e-mail addresses in the case of L. Alvarez

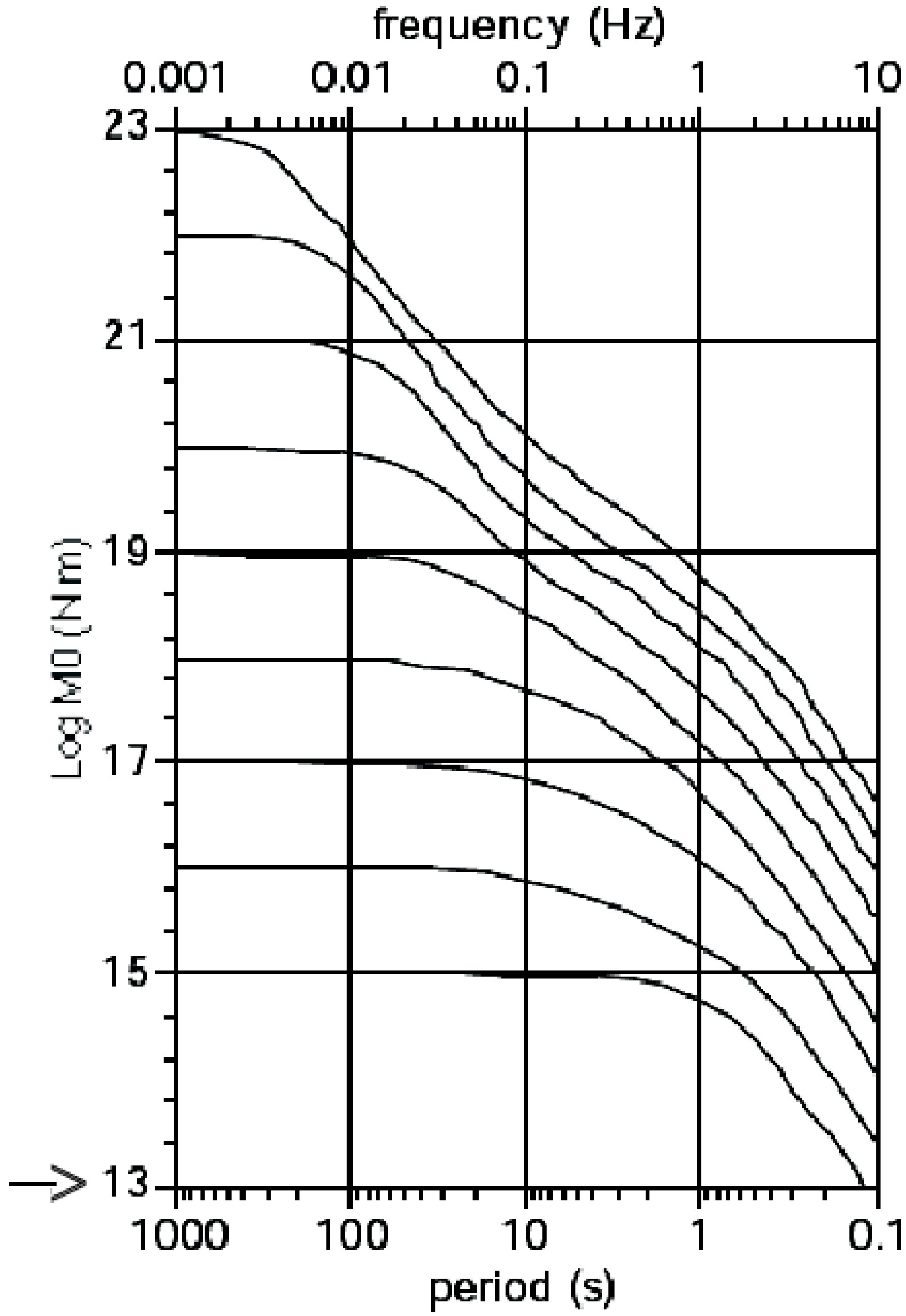
Abbreviations used

n_o_s – name of structure
n_o_p – name of profile
n_o_m – name of model

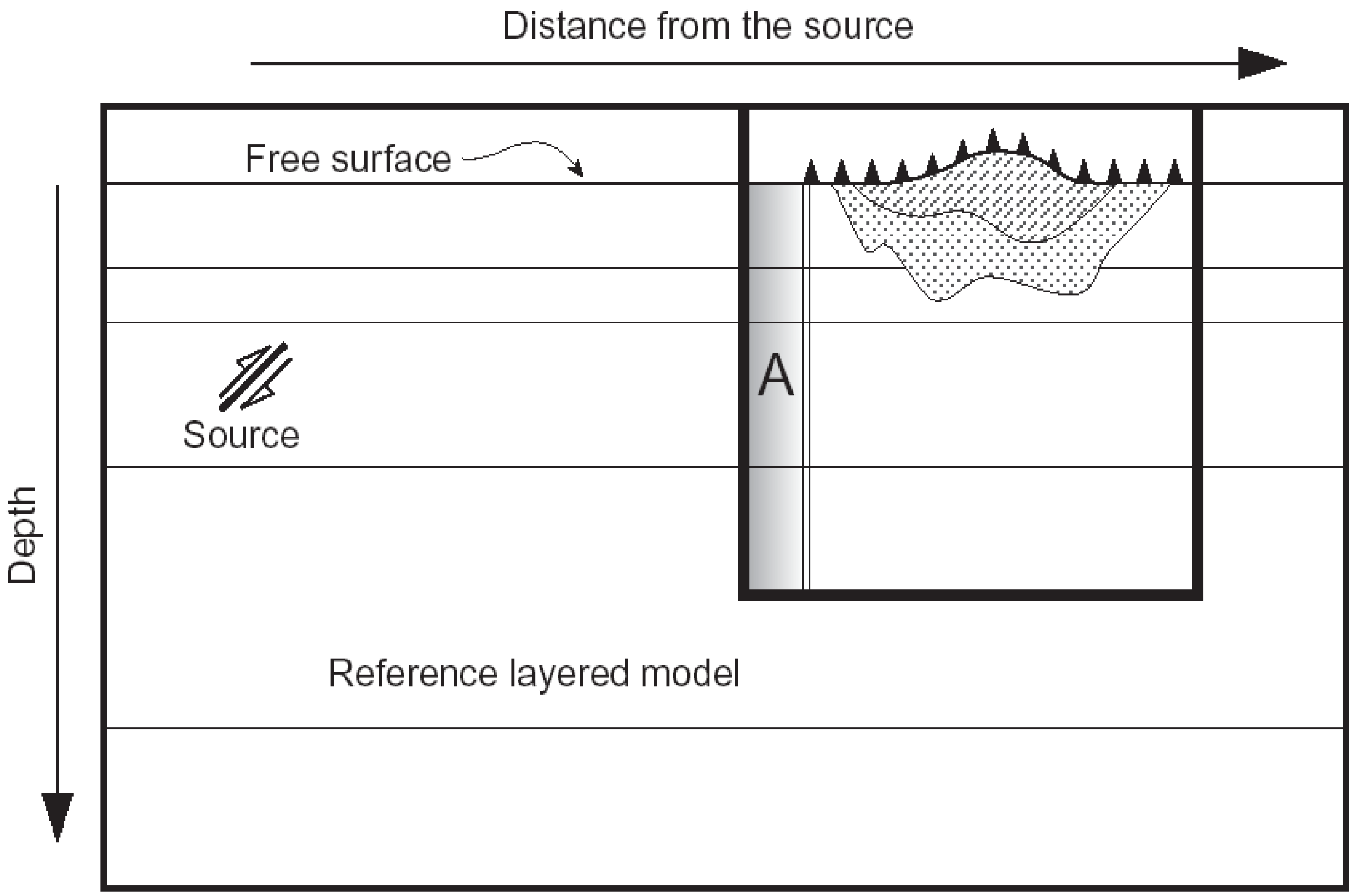
III) Some general considerations

Scaling of synthetic signals

Synthetic signals in the MS approach are obtained for a seismic moment of 10**20 dyne-cm. To obtain the corresponding seismogram for larger seismic moment, it is necessary to apply a scaling procedure that takes into account the differences in spectral content of finite faults. There are different scaling laws obtained from variety of theoretical models and others obtained from real data about earthquakes. In SAND group of ICTP it is preferred the use of the empirical scaling curves obtained by Gusev (1983), as they are presented by Aki (1987). In the procedure following in present manual, scaling of signals is done by program nfft. There are two possibilities, "nfft.out" that reads the Gusev curves from working directory, or nfftm.out that has included a set of standard curves of this kind.



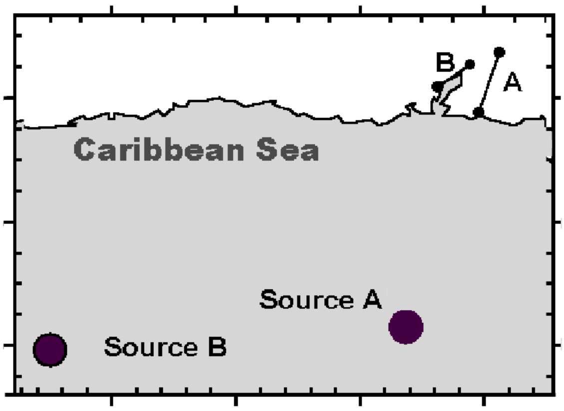
The hybrid approach to the 2D problem

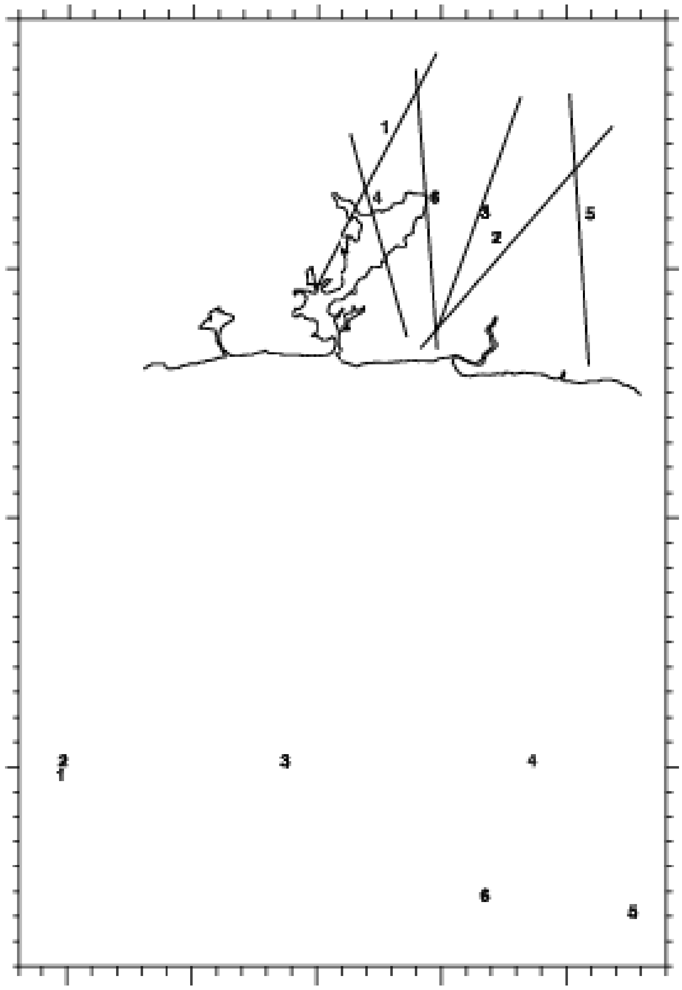


The hybrid approach consists in considering that the basin where the city is placed is embedded in a bedrock structure. The synthetic seismograms are calculated in two steps. From the source to the beginning of the profile a simple analytical modal summation (MS) procedure is applied, for the 1D structure of the regional bedrock model. Two columns of seismograms in depth are calculated just before the beginning of the profile. They act as the source of oscillations for the application of a finite difference procedure (FD) that will produce the synthetics seismograms along the 2D profile.

About selection of scenario earthquakes and tracing of profiles

The process of selection of scenario earthquakes is completely free. You have to select it (or them) from your knowledge of seismicity and tectonics of the region, from results of seismic hazards studies, etc. Once you have selected the source zone of scenario earthquakes you can pass to the tracing of profiles in the city. **The orientation of the profiles should coincide with the direction of the path source-city.** For extended source zones you can fix different trajectories source zone – city which allow you to use a wide range in profiles' orientation. In the following figure it is an example of extended source zone were scenario earthquakes affecting Santiago de Cuba city can occur. Profiles with different orientation can be traced.





About values of physical parameters of the soils

Sometimes it is not possible to get real values of the physical parameters of the soils. Instead of this, you can obtain geological description of the strata present in a profile. From this descriptions, an a priori simple classification of soils can be made, and you can use it for getting medium values of physical properties of the different soils present in your profile. In published papers you can obtain this information. Here are included data from some of them:

a) Medvedev, S.M. (ed.) (1977): Seismic Microzoning (in Russian), Moscow, Nauka, 248 pp.

b) Sadovskii, M. A.; Nersesov, I.L.; Medvedev, S.V.;Liamzina, G. A. (1973) : Main principles of the seismic microzoning (in Russian). Voprosii Inzheniernoi Seismologii, No. 15, Moscow, pp. 3-34.

c) Berge Thierry C, Lussou P, Hernández B, Cotton E, Gariel JC. (1999): Computation of the strong motions during the 1995 Hyogoken-Nambu earthquake, combining the k-square spectral source model and the discrete wavenumber technique. In: Proceedings of the Second International Symposium on the Effects of Surface geology on Seismic Motion, Yokohama, Japan, 1–3 December, 1998; Volume 3, The Effects of Surface Geology on Seismic Motion, Recent Progress and New Horizon on ESG Study, pp. 1414–1424.

In the first two there are presented average values of density and V_P (and V_S also in the second) for a wide variety of soils, while in the last there are presented some 1D structures with complete data (density, V_P, V_S, Q_P, Q_S).

a) Classification of soils and rocks, based on elastic properties modified from (Medvedev, S.V., 1977).

Soil or rock description	ρ(kg/m3)	V_P (km/s)
Artificial soils (fill or reclaimed land) composed by sand, sandy clays and clay, unconsolidated materials	1,3-1,7	0,10-0,50
Soft soils composed by sand, sandy clay, clay, silt	1,4-1,8	0,2-1,00
Compact and dense soils composed by gravel, sandy clays and sand	1,6-2,00	0,4-1,6
Compact, medium hard and hard soils, composed by sandy clays and clays, or weathered medium hard rocks: tuff, marls, limestones etc.	1,70-2,60	1,30-3,50
Weathered and fractured igneous and metamorphic rocks (Granite, basalt, etc.).	2,4-3,00	3,00-5,00
Same rocks without weathering	2,7-3,3	4,00-6,50

Rock or soil type	**V_P(Km/s)**
Rocks	
Granite--	5, 6
Limestone and metamorphic rocks--------------------	3, 5-4, 5
Weathered and fissured limestones and metamorphic rocks	1, 5-2, 3
Medium rocks	
Gypsum--	2, 4-3, 0
Marl---	2, 0-2, 6
Sandstone---	1, 4-1, 9
Gravel and conglomerate----------------------------	1, 3-2, 1
Soft soils	
Sand with gravel content--	1, 1-1, 6
Sand with medium size grains---------------------------------------	1, 0-1, 4
Sand with fine (clay or silt) content---------------------------------	0, 7-1, 2
Clay---	0, 9-1, 5
Sandy clay--	0, 7-1, 4
Fill, reclaimed land, etc. --	0, 2-0, 5

b) Average values of densities and seismic waves velocities (Sadovskii et al, 1973)

Rock type	**Tipo de roca**	**density (g/cm3) min-max**	**Vp(Km/s) min-max**	**average**	**Vs(Km/s) min-max**	**average**
I)Crystaline rocks	**I)Rocas cristalinas**					
Granites of depth zones	Granitos de zonas profundas	2.9	-	5.6	-	3.2
Granites,basalts,gabbros and other crystaline rocks	Granitos, basaltos, gabro y otras rocas cristalinas					
Not weathered,with natural humidity	No aireadas, humedad natural	2.5-3.8	2.0-7.0	3-5.5	1.0-4.8	2.8
Weathered, fisured non aqueous	Aireadas, fisuradas, no acuosas	1.6-2.35	1.0-3.3	1.2-3.0	0.2-0.6	0.5
The same but aqueous	Idem, acuosas	1.65-2.50	1.6-3.3	2.2-3.2	-	-
Dense limestones	Calizas densas	2.35-3.0	2.4-7.0	2.8-3.2	1.1-4	1.4-1.6
Dense dolomites	Dolomitas densas	2.4-3.05	3.5-7.0	4.0-6.5	1.7-4	1.8-2
Dense sandstones, argilites	Areniscas densas, argilitas	1.5-2.95	1.4-4.5	2.5-3.2	1.1-2	1.4-1.6
II)Semirock formations	**II)Formaciones semirrocosas**					
Gypsum (natural humidity)	Yesos (humedad natural)	2.1-2.4	2.0-5.5	2.5-3.2	1-3	1.2-1.8
Marls (natural humidity)	Margas (humedad natural)	1.8-2.8	1.1-6.0	2.6-3.5	0.4-3.4	0.5-0.6
Clayed schists	Esquistos arcillosos	2.6-2.7	1.6-4.7	2.4-4.0	0.6-2.8	0.7-2
III)Clastic soils with big fragments very weathered	**III)Suelos clásticos de grandes fragmentos o rocas muy alteradas**					
Conglomerated boulders, graves and coarse with sand fill	Conglomerados de guijarros, gravas y arenas gruesas con relleno arenoso					
With natural humidity	Con humedad natural	1.8-2.2	0.8-1.0	-	0.3-0.6	-
Aqueous	Acuosos	1.95-2.35	2.2-3.3	-	-	-
Conglomerates,graves and gross sand with clay fill	Conglomerados de guijarros, gravas y arenas gruesas con relleno arcilloso					
With natural humidity	Con humedad natural	1.8-2.2	0.8-1.3	-	0.3-0.8	-
Aqueous	Acuosos	2.0-2.35	2.3-3.4	-	-	-
Sandy clays with gravel and boulders with rock fragments (elluvium of high zones)	Sedimentos areno-arcillosos con gravas y guijarros no trabajados y redondeados o					

	con fragmentos rocosos (eluvios de zonas altas)					
With natural humidity	Con humedad natural	1.8-2.3	0.12-0.75	-	0.036-0.5	-
The same but aqueous	Acuosos	2.0-2.4	2.2-3.3	-	-	-
Place abounding in pebbles	Guijarrales lavados					
With natural humidity	Con humedad natural	1.7-2.0	0.5-1.1	-	0.3-0.8	-
Aqueous	Acuosos	1.9-2.3	1.8-3.3	-	-	-
IV)Sandstones, sands with different ganulometry and clean	**IV)Areniscas, arenas con diferente granulometría,limpias**					
With natural humidity	Con humedad natural	1.4-1.6	0.2-1.0	0.3-0.7	0.1-0.7	0.2-0.5
Aqueous	Acuosas	1.85-2.15	1.5-1.8	-	-	-
Weathered zone	Zona de aireación	1.3-1.4	0.08-0.4	0.1-0.3	0.04-0.3	-
Sands with clay content (up to 5%)	Arenas con material arcilloso (hasta 5%)					
With natural humidity	Con humedad natural	1.4-1.6	0.3-0.8	-	0.1-0.6	-
Aqueous	Acuosas	1.8-2.1	1.5-1.75	-	-	-
V)Clayish soils	**V)Suelos arcillosos**					
Clayish sands	Arenas arcillosas					
With natural humidity	Con humedad natural	1.45-1.9	0.3-0.7	0.4-0.6	0.1-0.35	-
Aqueous	Acuosas	1.8-2.0	1.7-1.9	1.8	-	-
Sandy clays	Arcillas arenosas					
With natural humidity	con humedad natural	1.65-2.05	0.3-0.9	0.5-0.8	0.08-0.45	-
Aqueous	Acuosas	1.70-2.1	1.6-1.9	-	-	-
Clays	Arcillas					
Whith natural humidity	Con humedad natural	1.3-2.0	0.85-1.4	1.1-1.3	0.2-0.7	0.3-0.5
Aqueous	Acuosas	1.80-3.25	1.75-2.2	-	-	-
Clays with sand & lime content & lime	Arcillas areno-limosas y limo					
With natural humidity	Con humedad natural	1.16-1.75	0.3-1.0	0.5-0.7	0.1-0.7	0.2-0.4
Saturated, inmediatly after steeping	Saturadas, inmediatamente despues de remojadas	1.60-2.60	0.15-0.5	-	0.02-0.08	-
Aqueous	Acuosas	1.60-2.60	1.5-1.8	1.6-1.7	0.1-0.7	-
VI)Fill soils	**VI)Suelos de relleno**					
Non saturated	No saturados	1.30-1.50	0.03-0.3	0.2-0.3	0.01-0.2	0.1-0.2
Saturated	Saturados	1.50-1.80	1.5-1.7	-	-	-
VII)Vegetable layer	**VII)Capa vegetal**	1.40-1.85	0.04-0.5	0.08-0.3	0.01-0.2	-

c) Tables took from Berge-Thierry et al. (1999)

ANNEXE 1

The geological structures described in these 3 tables have been used to compute the 3 components at KBU (at depth = 0 m), and to calculate the horizontal components for RKI, KB1, KB2, KB3 and KB4 evaluated respectively at 110 *m*, 20.5 *m*, 20. *m*, 34.1 *m* and 30.2 *m* at depth: these horizontal seismograms evaluated at depth being the inputs of the non-linear process.

Table 2: Soil characteristics for KBU.

Interf. Depth (m)	Vp (m/s)	Vs (m/s)	ρ (kg/m^3)	Qp	Qs
0	2200	1200	1800	150	40
20.	3200	1800	2100	400	200
400.	5150.	2850.	2500	500	200
550	5500	3200	2600	550	300
5000	6000	3460	2700	900	400
18000	6700	3870	2800	1200	500

Table3: Soil characteristics for KB1 and KB2.

Interf. Depth (m)	Vp (m/s)	Vs (m/s)	ρ (kg/m^3)	Qp	Qs
0	1600	400	1700	150	40
400.	2500	1000	2200	350	100
800.	4250.	2850.	2300	400	150
5000	6000	3460	2800	1300	600
18000	6700	3870	2800	1200	500

Table 4: Soil characteristics for KB3, KB4 and RKI.

Interf. Depth (m)	Vp (m/s)	Vs (m/s)	ρ (kg/m^3)	Qp	Qs
0	1400	100	1400	50	20
20.	1600	400	1800	200	50
450.	2500.	1000.	2200	350	100
900	4250	2850	2300	400	150
5000	6000	3460	2800	1300	600
18000	6700	3870	2800	1200	500

ANNEXE 2

These 5 tables describe the geological structures and physical parameters used in the Cyberquake code in order to compute the non-linear transfer function of surrounding soft sediments at KB1, KB2, KB3, KB4 and RKI stations. These transfer functions have been applied on horizontal components only. These values have been defined after the informations given in the guidelines (borehole description). The symbol & seems that for example clay & silt are in an equal proportion, whereas the symbol - significates that sand dominates in a sand - gravel material.

Table 5: Surrounding layers at KB1.

	Deposit Type	Thickness (m)	Vs (m/s)	ρ (kg/m³)
layer 1	Surface deposit	0.5	150	1500
layer 2	Sand	3.8	150	1500
layer 3	Sand & Gravel	1.6	250	1500
layer 4	Gravel	0.6	275	1500
layer 5	Sand	1.1	200	1600
layer 6	Sand & Clay	0.8	200	1600
layer 7	Sand	3.1	225	1600
layer 8	Sand & Clay	1.1	225	1700
layer 9	Sand	3.5	250	1700
layer 10	Sand & Gravel	4.1	325	1800
layer 11	Sand	0.3	250	1800
Bedrock	Bedrock	infinite	1500	2400

Table 6: Surrounding layers at KB2.

	Deposit Type	Thickness (m)	Vs (m/s)	ρ (kg/m³)
layer 1	Sand	3.0	150	1500
layer 2	Sand & Gravel	2.9	200	1500
layer 3	Gravel	0.2	250	1500
layer 4	Sand - Gravel	1.0	200	2000
layer 5	Silt	0.2	200	1600
layer 6	Sand & Gravel	2.3	275	1600
layer 7	Sand & Gravel	4.5	300	1800
layer 8	Sand & Gravel	5.9	300	1800
Bedrock	Bedrock	infinite	1500	2400

Table 7: Surrounding layers at KB3.

	Deposit Type	Thickness (m)	Vs (m/s)	ρ (kg/m^3)
layer 1	Soil Deposit	6.6	150	1500
layer 2	Sand	3.4	200	1500
layer 3	Sand & Silt	2.5	175	1600
layer 4	Sand - Gravel	3.0	225	1600
layer 5	Sand & Silt	1.3	200	1600
layer 6	Sand	1.1	250	1700
layer 7	Sand & Gravel	4.5	300	1800
layer 8	Sand & Gravel	5.0	350	1800
layer 9	Sand	5.5	260	1800
layer 10	Sand & Gravel	2.0	375	2000
layer 11	Sand & Gravel	2.0	275	2000
Bedrock	Bedrock	infinite	2085	2600

Table 8: Surrounding layers at KB4.

	Deposit Type	Thickness (m)	Vs (m/s)	ρ (kg/m^3)
layer 1	Soil Deposit	18.6	150	1500
layer 2	Silt	3.0	150	1600
layer 3	Sand	1.1	216	1800
layer 4	Silt	0.8	185	1800
layer 5	Sand-Gravel	6.7	265	2000
Bedrock	Bedrock	infinite	2085	2600

Table 9: Surrounding layers at RKI.

	Deposit Type	Thickness (m)	Vs (m/s)	ρ (kg/m^3)
layer 1	Gravel & Sand	3.5	175	1900
layer 2	Sand & Gravel	3.0	175	1900
layer 3	Sand & Gravel	6.0	200	1900
layer 4	Sand & Gravel	5.0	200	1900
layer 5	Sand & Gravel	3.0	250	1900
layer 6	Clay & Silt	10	200	1650
layer 7	Clay & Silt	4.5	220	1700
layer 8	Sand & Gravel	11.	380	1800
layer 9	Sand & Gravel	24.	340	1900
layer 10	Clay & Silt	20.	270	1600
layer 11	Sand & Gravel	10.	430	1900
layer 12	Clay & Silt	5.0	350	1700
Bedrock	Bedrock	infinite	3800	2500

ANNEXE 3

These 5 tables describe the velocity models used to compute the vertical component at KB1, KB2, KB3, KB4 and RKI stations. For the computation of the vertical component the stations are supposed to be at depth 0 m.

Table 10: Soil characteristics for KB1: vertical component only.

Interf. Depth (m)	Vp (m/s)	Vs (m/s)	ρ (kg/m^3)	Qp	Qs
0	1050	150	1500	150	40
4.3	1500	260	1500	200	50
6.5	1200	200	1600	200	50
8.4	1350	250	1750	250	50
20.5	2500	1000	2200	35	100
800	4250	2850	2300	400	150
5000	6000	3460	2800	1300	600

Table 11: Soil characteristics for KB2: vertical component only.

Interf. Depth (m)	Vp (m/s)	Vs (m/s)	ρ (kg/m^3)	Qp	Qs
0	1050	150	1500	150	40
21.6	1500	200	1800	200	50
23.5	2500.	265.	2000	300	100
30.2	4250	2850	2300	400	150
20.5	2500	1000	2200	35	100
5000	6000.	3460	2800	1300	600
18000	6700	3870	2800	1200	500

Table 12: Soil characteristics for KB3: vertical component only.

Interf. Depth (m)	Vp (m/s)	Vs (m/s)	ρ (kg/m^3)	Qp	Qs
0	1050	170	1500	200	50
10.	1200	220	1600	200	100
18.4	1550	300.	1800	200	100
28.9	2500	350	2000	350	100
34.1	4250	2085	2600	400	150
900	4250	2850	2300	400	150
5000	6000	3460	2800	1300	600
18000	6700	3870	2800	1200	500

Table 13: Soil characteristics for KB4: vertical component only.

Interf. Depth (m)	Vp (m/s)	Vs (m/s)	ρ (kg/m^3)	Qp	Qs
0	1050	150	1500	200	50
21.6	1500	200	1800	200	50
23.5	2500	265	2000	350	100
30.2	4250	2085	2600	400	150
34.1	4250	2085	2600	400	150
900	4250	2850	2300	400	150
5000	6000	3460	2800	1300	600
18000	6700	3870	3000	1700	800

Table 14: Soil characteristics for RKI: vertical component only.

Interf. Depth (m)	Vp (m/s)	Vs (m/s)	ρ (kg/m³)	Qp	Qs
0	825	187.5	1900	100	50
16.5	1360	220	1800	150	50
50	1365	315	1750	150	50
30.2	4250	2085	2600	400	150
105	1400	400	1850	200	100
450	2500	1000	2200	350	100
900	4250	2850	2300	400	150
5000	6000	3460	2800	1300	600
18000	6700	3870	3000	1700	800