ERZSLR-DAS

DAS RESPONSE FOR A STRATIFIED ELASTIC MODEL

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This program is designed for the calculation of the seismic response of a horizontally layered medium to a general point source specified by a moment tensor or surface force

Model File Specification

The calculations use a velocity and attenuation model in the following form:
- all velocities are in kilometres/second
  depths or thicknesses in kilometres
  densities in Mg/metre cubed

Example Model file : dr2.mod

```
 dr2                                                          Model name
     6        0                                              # layers, ndt
 3   1.500    0.800     2.03     0.130    0.001     0.002
 3   1.900    1.000     2.15     0.040    0.001     0.002
 3   2.200    1.200     2.30     0.480    0.001     0.002
 3   3.300    1.700     2.50     0.850    0.001     0.002
 3   4.300    2.300     2.60     1.400    0.001     0.002
 3   4.500    2.400     2.65     3.000    0.001     0.002

nr   alpha    beta      rho      thick     1/Qa      1/Qb
   (P km/s) (S km/s)  (Mg/m3)    (km)
```

The index `nr` controls the number of reverberations in the layer

```
nr = 0  - no reflection from top of layer
   = 1  - no internal multiples in layer
  >= 3  - all internal multiples in layer
```

`nr =2` gives a partial set of internal multiples and is not generally useful

In this application the *thickness* of layers is specified.

Theoretical Seismogram Calculation

The calculation of the seismic response of a horizontally layered elastic medium to a buried seismic source is carried out by building up the response in the slowness-frequency domain. Calculations can be performed for ground displacement, velocity or acceleration as well as the DAS reposne for close sources based on the difference of ground velocity resolved along the Das cable and an analytic approximation for wavelengths long compared to the gauge length for sources at greater distance.

All the internal calculations are carried out in memory with a restriction to:
2500 slownesses and 1200 frequencies
An adaptive scheme is provided that reduces the slowness sampling for larger slownesses that improves the accuracy of the integration.

Seismograms at each distance are produced by

a) an integration over slowness at each frequency with a distance specific slowness factor
b) a Fast Fourier transform over frequency

The theoretical seismogram program `erzslr-das` is used with a control file which specifies the model file to be used and the parameters for ray parameters and frequencies and multiples to be used in the calculation

```
erzslr-das < ers-reg.cmd
```

Command file structure

The command file (`ers-reg.cmd`) has the form

```
"ERZSLR-das   ck140 DR"                 # Title
"jdr-ck-2h.txz"                         # File for T-X seismogram output
YE                                      # Adaptive slowness
"ck140ft.mod"                           # Velocity model file
"DR"                                    # Response (GD,GV,GA,DL,DR,DV)
"HS"                                    # Surface Condition (HS,H1,WF,WS)
  1200                                  # Number of slownesses (<2500)
  0.00                                  # Minimum slowness
  0.33                                  # Maximum slowness
20                                      # Slowness taper plo (n samples)
20                                      # Slowness taper phi (n samples)
"WA"                                    # Wavelet input or Ricker (WA/RI)
"ewd.wav"                               # Wavelet file
"YE"                                    # Exponential damping? (YE/NO)
  4096                                  # Number of time points
  0.02                                  # Time step
   0.05    0.10                         # Frequency taper (low)
   8.0     12.0                         # Frequency taper (high)
    5.0                                 # Dominant frequency [RI]
"MT"                                    # Moment tensor or Force (MT/SF)
 -0.1531    0.5161    0.1230    0.00    # Moment tensor & Force Components
  0.5161   -0.5449    0.5611    0.00
  0.1230    0.5611    0.6980    0.00
   4.00                                 # Depth of source
   0.001   125.000                      # Cable depth, (DL) source offset
"TID-J1.drs"                            # Range and azimuth file
  0.00                                  # Reduction slowness
  10.0                                  # Start time (reduced)
"NO"                                    # Debug/frequency-wavenumber (YE/NO)
"NO"                                    # Debug/waveform (YE/NO)
```

The seismograms are produced in ***ZST*** format (ascii) for subsequent plotting.

Explanation of input parameters

Note all dimensions are in kilometres and times in seconds

1) Title for Run
Character string to be used as header for run

2) File for T-X seismogram output
Character string for name of file to receive T-X seismogram
output in zst format

3) Use of adaptive slowness
`YE` – adaptive slowness integration used
`NO` – uniform spacing in slowness

4) Velocity model file:
Character string for name of file with model specification
the model file should be in the standard model file format
(ndt = 0 for layer thickness specification)

5) Type of Response.
`GD` – ground displacement
`GV` – ground velocity
`GA` – ground acceleration
`DL` – DAS response local – differenced velocity resolved along cable
`DR` – DAS response regional – strain rate
`DV` – DAS response regional – velocity resolved along cable

6) Surface Condition:
The various boundary conditions to be applied at the surface are specified by mnemonics
`HS` – A full calculation for a half space with elastic free surface conditions
`H1` – Calculation for a half space with only first order surface reflections included
`WF` – Calculation for a non-reflecting surface but with displacement corrected for free surface amplification
`WS` – Calculation for a non-reflecting surface

7) Number of slownesses (<2500)
Integer specifying the number of slownesses to be used.

If adaptive slowness is specified, the density of slowness points is increased at both small and large slownesses. This improves the accuracy of near-offset traces, and generally allows better results to be achieved with a single broad slowness panel.
Too coarse a slowness choice will give rise to inadequate sampling which usually gives oscillations in the seismograms at the highest frequency used.

8) Minimum slowness
Lower edge of slowness band in s/km

9) Maximum slowness
Upper edge of slowness band in s/km

The theoretical seismograms for a single slowness panel will often display numerical arrivals with the slownesses of the upper and lower limits of the window. These can be of significant amplitude unless tapering is applied

10) Slowness taper `plo` (n samples)
Integer specifying the number of samples at the lower end of the slowness window over which the response is linearly tapered to zero

11) Slowness taper `phi` (n samples)
Integer specifying the number of samples at the upper end of the slowness window over which the response is linearly tapered to zero

12) Far-field time function input
`WA` – wavelet file read in
`RI` – Ricker wavelet used (dominant frequency specified in 18)

13) Waveflet file name
File name should be specified even if `RI` option used

14) Exponential damping
Specification of exponential damping in time in construction of seismograms (`YE` or `NO`)

If `YE` is specified the calculations are carried out in the complex frequency domain with an effective exponential damping applied in time. This improves the situation with aliasing in time
and so shorter total time intervals can often be employed.
However weak spatially aliased arrivals late in the record are magnified dramatically when exponential gain is applied to recover the true time response. As a result when exponential gain is used only the first 3/4 of the time interval has gain recovery applied, the remaining 1/4 should not be regarded as useful.

If `NO` is specified then the calculations are all performed for real frequency and care needs to be taken to have the time interval of calculation long enough to avoid aliasing in time.

15) Number of time points
Integer power of 2, e.g., 4096, specifying the total number of time points in the theoretical seismograms

16) Time step
Sampling interval in time in seconds, i.e., 4 ms sampling is specified as 0.004

17) Frequency taper (low)
A cosine taper in frequency is applied between the two specified frequencies
e.g. for. 0.05 0.10
zero response is specified for frequencies less than 0.05 Hz and unit response for frequencies higher than 0.10 Hz with a cosine taper between.

18) Frequency taper (high)
A cosine taper in frequency is applied between the two specified frequencies e.g. for 8.0 12.0

unit response is specified for frequencies less than 8 Hz and zero response for frequencies higher than 12 Hz with a cosine taper between.

Care should be taken that the number of discrete frequencies in the pass band of the band-pass filter does not exceed 1200 or array bound violations will occur with unpredictable results

19) Dominant Frequency

Used only if `RI` option used for wavelet

20) Moment tensor or Surface force?

`MT` – Moment tensor used
`SF` – Surface forces used

21-23) Moment tensor and force components

The radiation characteristics of the point source are specified by moment tensor or force components (only one used)
The components are entered as:

```
Mxx   Mxy   Mxz   Fx
Myx   Myy   Myz   Fy
Mzx   Mzy   Mzz   Fz
```

Note:

```
Mxx  Mxy  Mxz  using Harvard  MTT  -MTF  MRT
Myx  Myy  Myz    notation     -MTF   MFF  -MRF
Mzx  Myz  Mzz                 MRT  -MRF  MRR
```

24) Depth of source

The depth of the source below the surface in km
i.e. 10 metres is specified as 0.010

Note the program is built around a model of a point source
(an extended source can be simulated in part by weighting dipole sources or by summing the response from different sources)

25) DAS cable depth, source offset

Specification of DAS cable depth in km (not currently used)
For `DL` option – offset of source from cable in km

26) Range and azimuth file

Provide name of range and azimuth file in appropriate format:
with number of traces `nx` at head (Currently `nx`<200)

`GD, GV, GA` options – `nx` values
`xs, az` - range in km, azimuth at sources [deg]
`DL` option (`.dls` file) – `nx` values
`xc, caz, xg1,az1, xg2,az2`
- position along cable, cable azimuth, range and azimuth to ends of gauge interval

`DR, DV` options (`.drs` file) – `nx` values
`xs ,azd ,xd, caz`
- epicentral distance [km], azimuth from source, position on cable, cable azimuth,

27) Reduction slowness
Value in s/km for the slowness to be used to adjust the time axis
to follow specific arrivals.

28) Start time (reduced)
The beginning of the theoretical seismograms allowing for the reduction slowness.
Use 0.00 to have the theoretical seismograms starting at the source instant.

29) Debug/frequency-wavenumber (YE or NO)
30) Debug/waveform (YE or NO)
Setting either of these parameters to YE generates copious output and should not be necessary in normal use

COMMAND FILES:

The command files have a fixed syntax:

commands are read with a2
file names are read with a30
titles, labels with a72
numbers are read free formatted

for each instruction a brief explanation is given
in columns 41-80 for commands, numbers
in columns 72-80 for titles etc

ZST format for seismograms:

The information is stored as formatted Fortran output
in the following simple form

`nrange` - number of distances
`ncomp` - number of components for each distance

...for each component: (`nrange*ncomp` records)
`range` - distance in km {`G.`} or cable position {`D.`}
`azim` - azimuth (degrees)
`ichar` - component identifier (char*4)
`delt` - time sampling interval
`ntim` - number of time points
`pcal` - reduction slowness for calculation
`tcal` - start time of calculation (absolute)
`smax` - maximum value of seismogram
`(seis(k), k=1,ntim)` - time series
...end component loop

`ncomp = 1` for `DL, DR, DV` options, `ncomp=3` for `GD, GV, GA` options