Using Ambient Vibration Array Techniques for Site Characterisation

Dispersion Curve Inversion with Dinver

Tutorial

December 6th-12th, Thessaloniki, Greece

Dispersion Curve Inversion with Dinver

1. Calculating a theoretical dispersion curve
   - ⇒ Introduction to gpdc
   - ⇒ Playing with gplivemodel
2. Inversion of dispersion curves
   - ⇒ Targets
   - ⇒ Parameterization
   - ⇒ Running inversion processes
   - ⇒ Viewing results

SESARRAY PACKAGE

GEOPSY

array tools

H/V | damping | FK | Capon | MSPAC | MASW

figue
figures

gp tools
Dispersion curves
Ellipticity curves
Autocorr. Curves
...

Post-processing

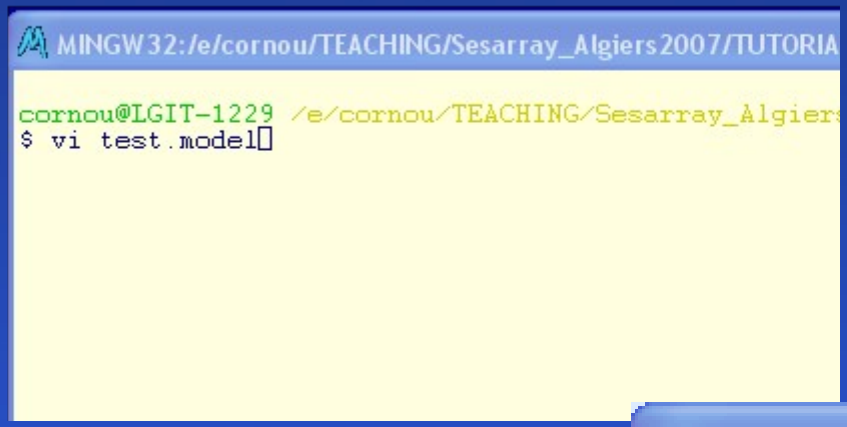
max2curve | spac2disp

build_array
Array response

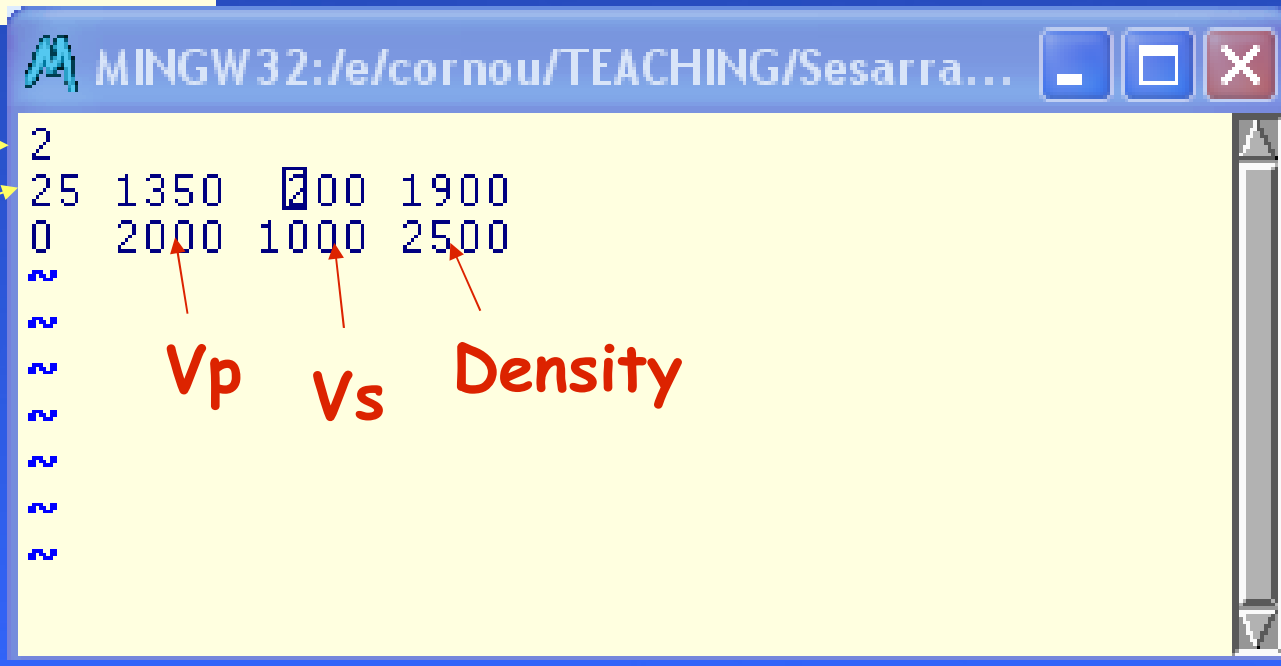
DINVER
inversion

1. Calculating a theoretical dispersion curve

Create a text file with model parameters



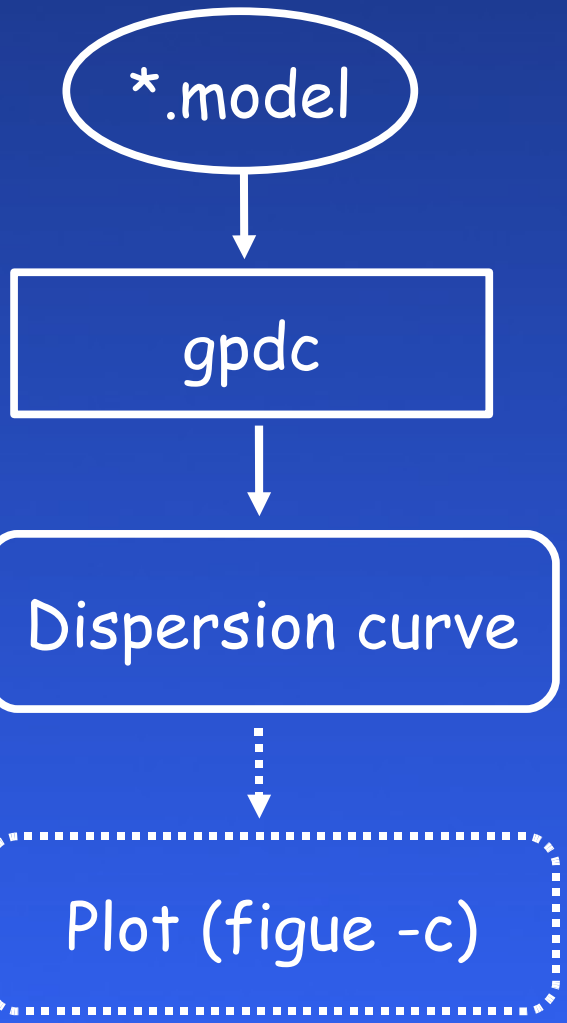
(vi, notepad,... any text editor)



gpdc: a command line tool for dispersion curve computation

MINGW32:/e/cornou/TEACHING/Sesarray_Algiers2007/TUTORIALS

```
cornou@LGIT-1229 /e/cornou/TEACHING/Sesarray_Algiers2007/TUTORIALS
$ gpdc --help
Usage: gpdc [OPTIONS] [FILE]

Compute dispersion curve for layered models given through stdin or FILE.

Format for layered models:
  Line 1   : <number of layers including half-space for first model>
  Line 2   : <thickness (m)> <Vp (m/s)> <Vs (m/s)> <Density (kg/m3)>[ <Qs> <Qp>]
  ....
  Line n   : 0 <Vp (m/s)> <Vs (m/s)> <Density (kg/m3)>[ <Qs> <Qp>]
  Line n+1: <number of layers including half-space for second model>
  ....

Quality factors are not mandatory. If not specified, pure elastic computation is
performed. Any number of models can be given as input.

Generic options:
  -help                    Show help about options
  -version                 Show version information
  -reportbug               Start bug report dialog, information about bug is
                           passed through stdin. This option is used internally
                           to report bugs if option -nobugreport is not
                           specified.
  -nobugreport             Do not generate bug report in case of error

Gpdc options:
  -n <count>               Number of samples (default=100)
  -L <n modes>             Number of Love modes (default=0)
  -R <n modes>             Number of Rayleigh modes (default=1)
  -group                   Switches to group slowness (default=phase)
  -s <sampling>            Defines the sampling type:
                             period     regular sampling in period
                             frequency  regular sampling in frequency
                             log        regular sampling in log(frequency)
                           (default)
  -min <min>               Minimum of range for dispersion curve (default=0.2)
  -max <max>               Maximum of range for dispersion curve (default=20)
  -n <count>               Number of samples (default=100)

Examples:

        gpdc < test.model

    Calculate fundamental Rayleigh dispersion curve from 0.2 Hz to 20 Hz for
    model 'test.model'.

        gpdc -L 1 -R 2 < test.model

    Calculate fundamental Love mode and fundamental and first higher mode for
    Rayleigh.

        gpdc < test.model | figue -c
```



```
   gpdc < test.model
```

Calculate fundamental Rayleigh dispersion curve from 0.2 Hz to 20 Hz for model 'test.model'.

```
   gpdc -L 1 -R 2 < test.model
```

Calculate fundamental Love mode and fundamental and first higher mode for Rayleigh.

```
   gpdc < test.model | figue -c
```

Calculate the same dispersion curve and plot it.

```
   gpdc < test.model | figue -c -m dc.mkup
```

Show the same dispersion curve on a log-log plot. 'dc.mkup' is a tar.gz file containing an xml description of the graphic format, it can be generated from figue's interface.

MINGW32:/e/cornou/TEACHING/Sesarray_Algiers2007/TUTORIALS

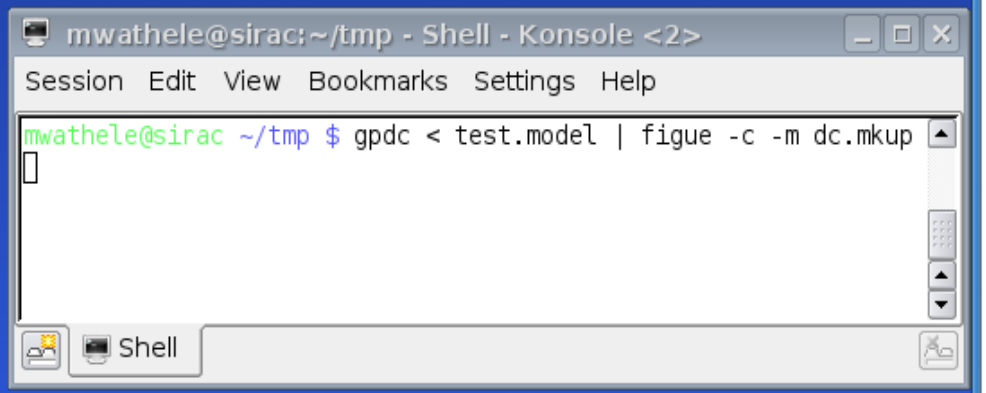
```
cornou@LGIT-1229 /e/cornou/TEACHING/Sesarray_Algiers2007/TUTORIALS
$ gpdc -R 2 < test.model > target.dc
```

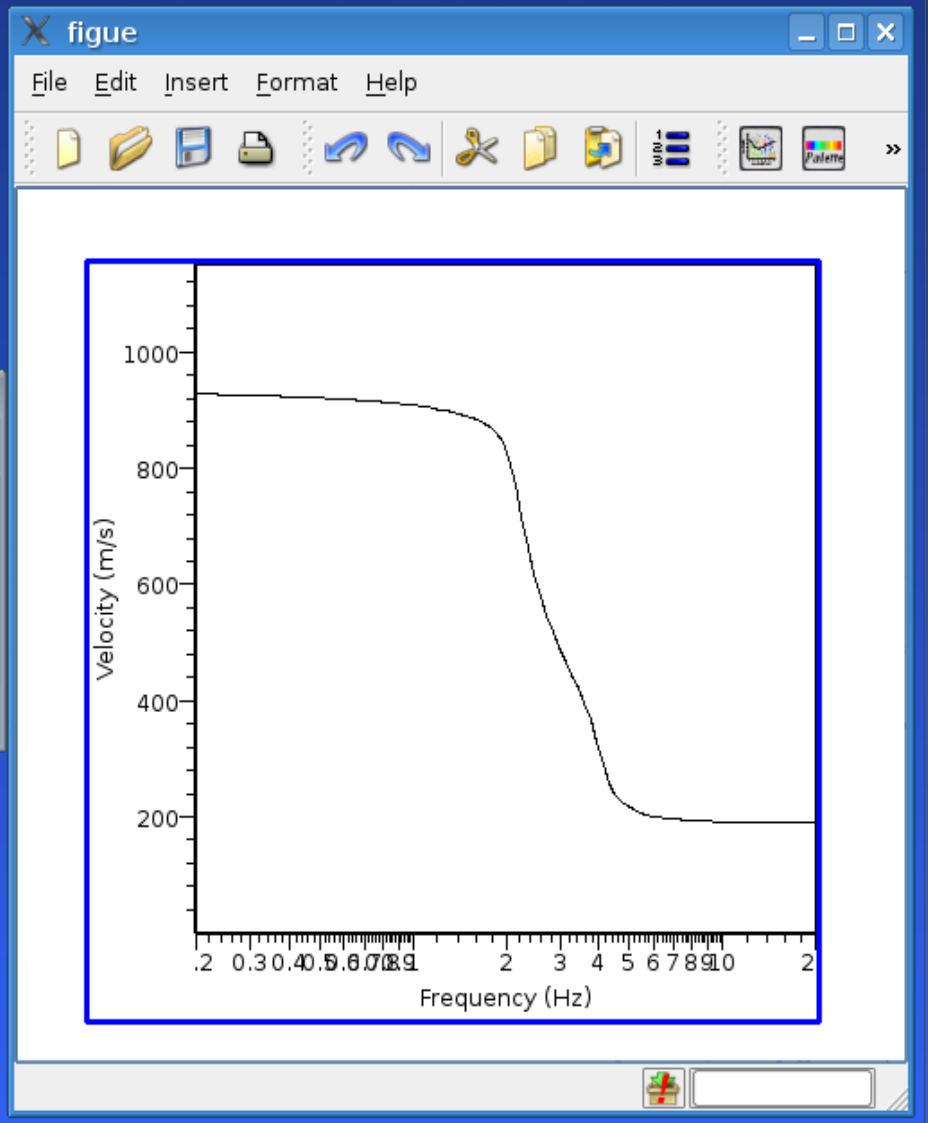
MINGW32:/e/cornou/TEACHING/Sesarray_A...

```
# 2 Rayleigh dispersion modes
# Mode 0
0.2 0.00107739331509553
0.209523150557933 0.00107763758157074
0.219499753098611 0.00107789409424396
0.229951399079547 0.00107816323021893
0.240900708051756 0.00107844578444416
0.252371376613204 0.0010787424664883
0.264388229693206 0.0010790540286263
0.276977274278775 0.0010793812691111
0.290165755699188 0.00107972503579373
0.303982216590587 0.00108008623014239
0.318456558668219 0.00108046581172061
0.333620107440012 0.00108086480319564
0.349505680001537 0.00108128429596249
0.366147656059074 0.00108172545648591
0.383582052334498 0.00108218953348406
0.401846600513009 0.00108267786610392
0.420980828902404 0.00108319189327193
```

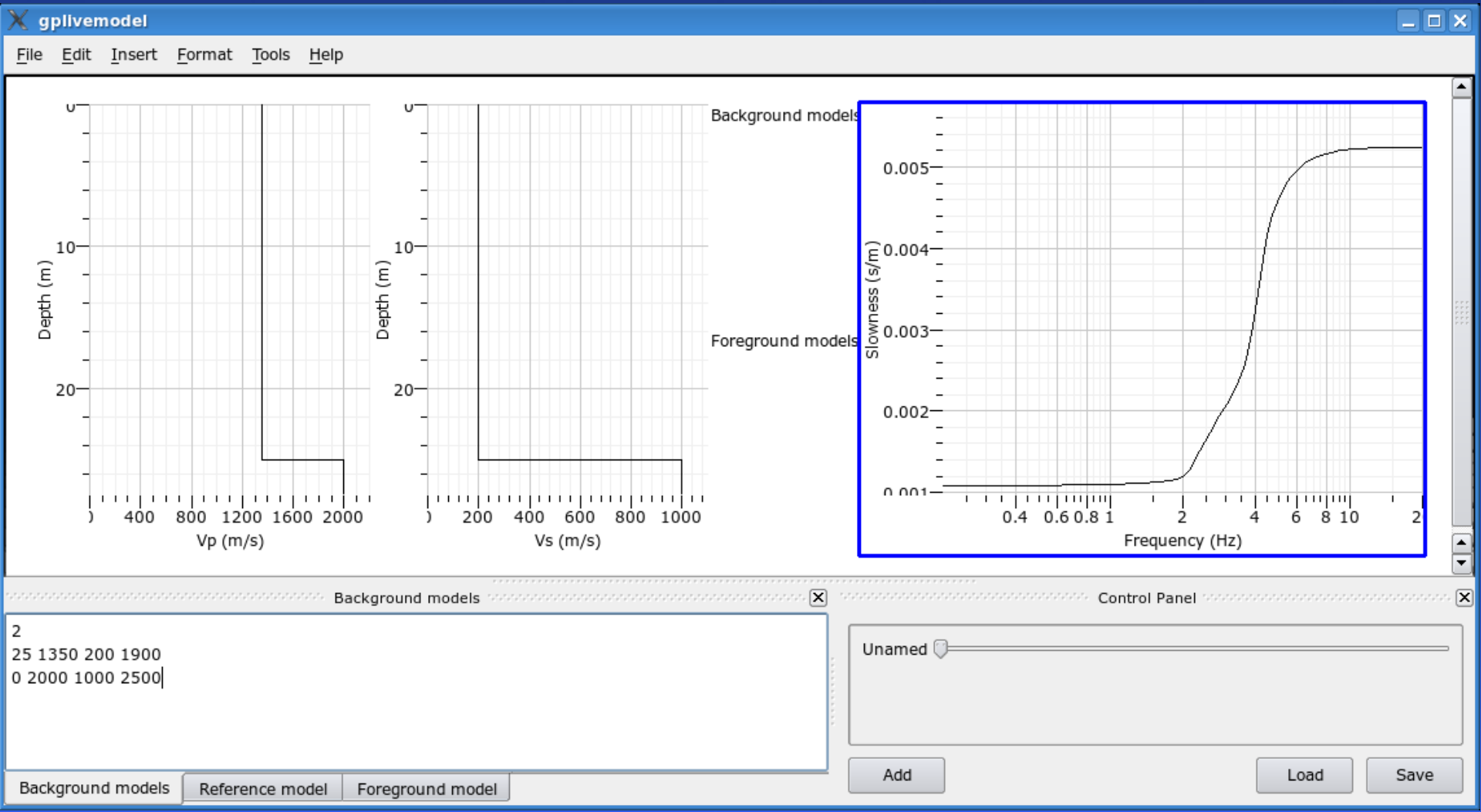
MINGW32:/e/cornou/TEACHING/Sesarray_A...

```
17.3949800523557 0.00524099612354591
18.2232551223098 0.00524117200283951
19.0909691332367 0.00524129289654945
20 0.00524137441070279
# Mode 1
2.24664806595606 0.0010322920874912
2.35362390487 0.00106091110454442
2.46569347888413 0.00107854340076219
2.58309933002977 0.00109059866066247
2.70609554915962 0.001099722720448
2.83494832585361 0.00110721447007284
2.96993652450893 0.00111376540442095
3.11135228786095 0.00111977851655673
3.25950166924129 0.00112551170920067
3.41470529494138 0.0011311500807528
3.57729905811487 0.00113684443785493
3.74763484572077 0.00114274232371332
3.92608130008054 0.00114901694885534
4.1130246166973 0.00115591068556711
```

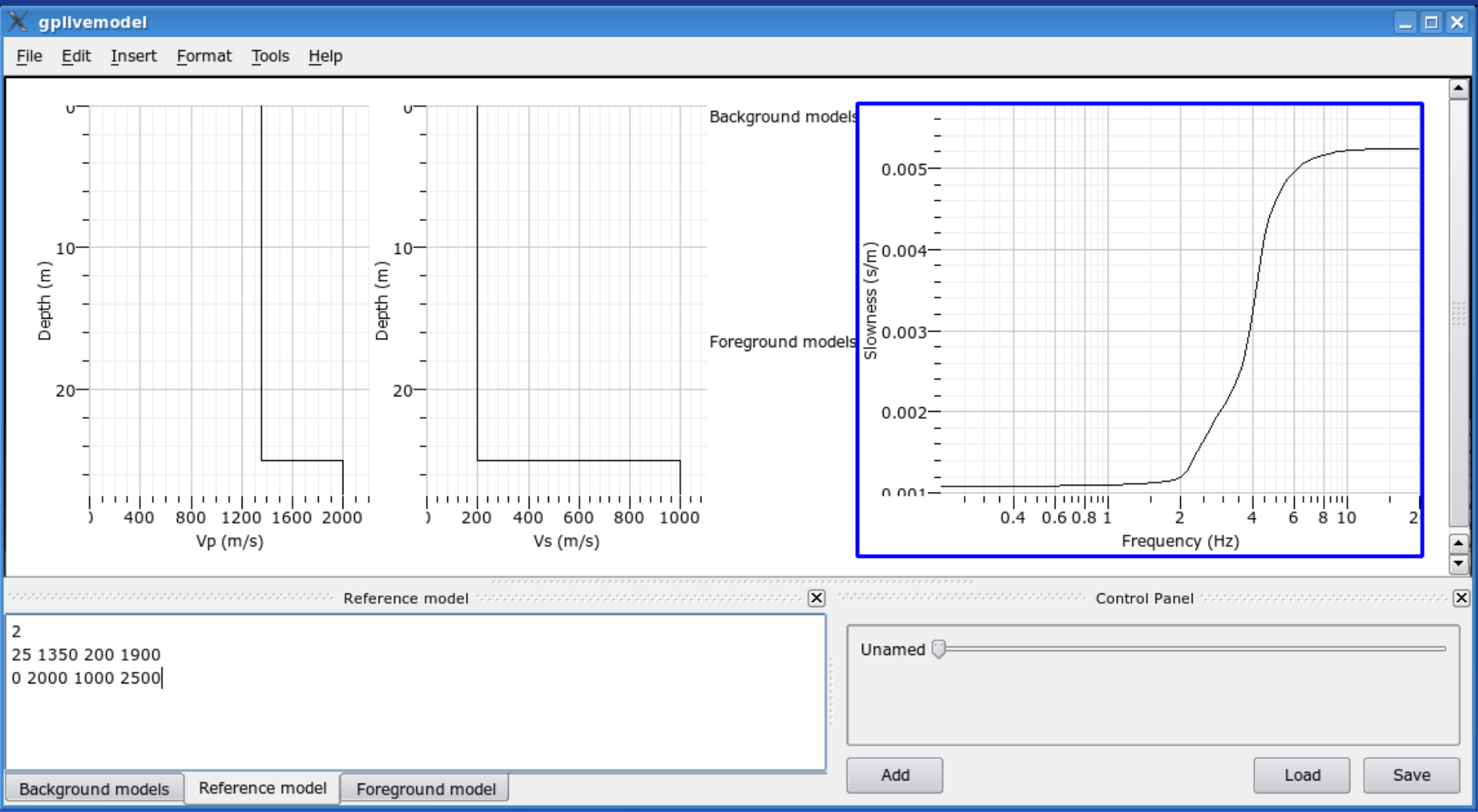

mwathele@sirac:~/tmp - Shell - Konsole <2>
Session Edit View Bookmarks Settings Help
mwathele@sirac ~/tmp $ gpdc < test.model | figue -c -m dc.mkup
Shell


figue
File Edit Insert Format Help
Velocity (m/s)
1000
800
600
400
200
Frequency (Hz)

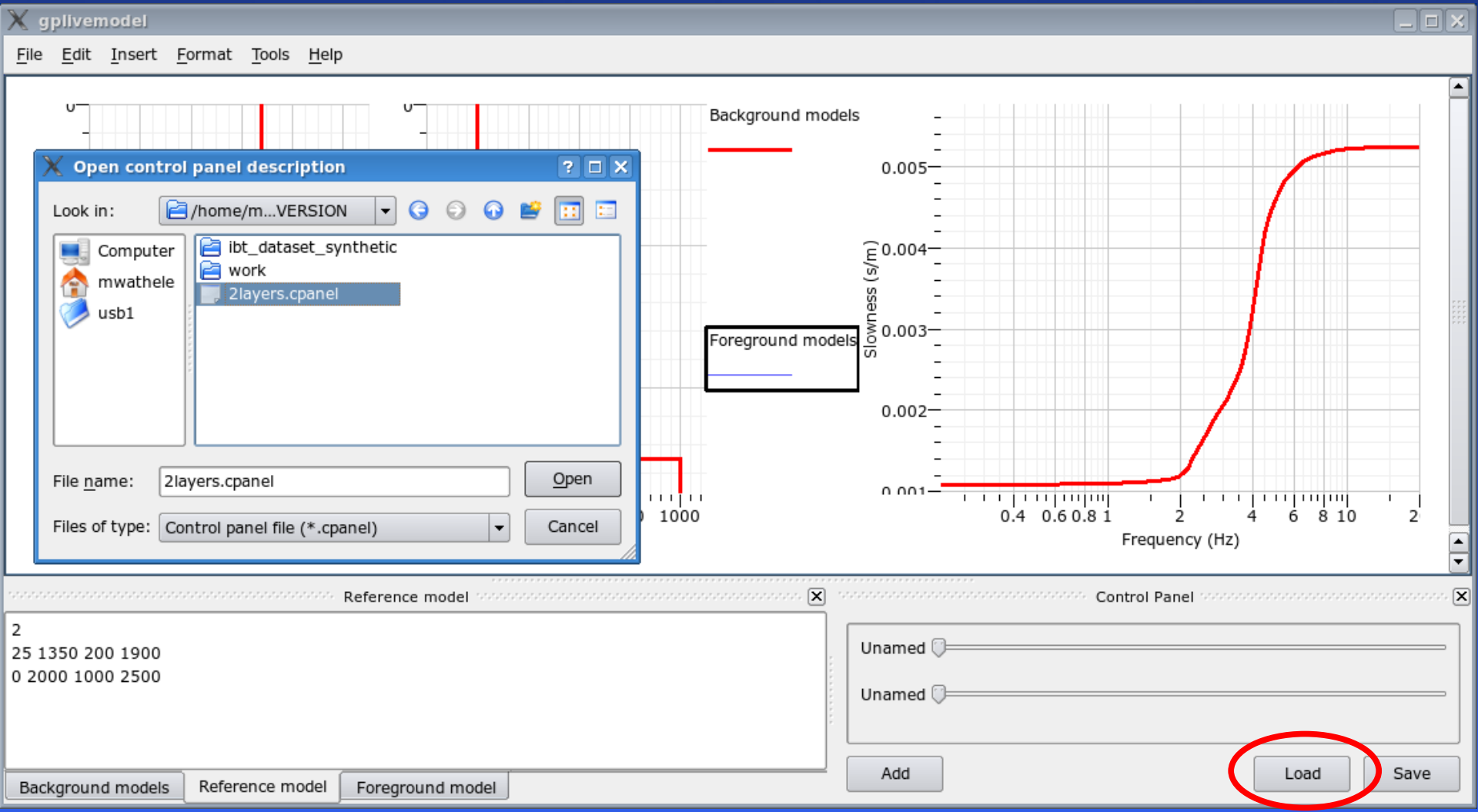
Gplivemodel : background models



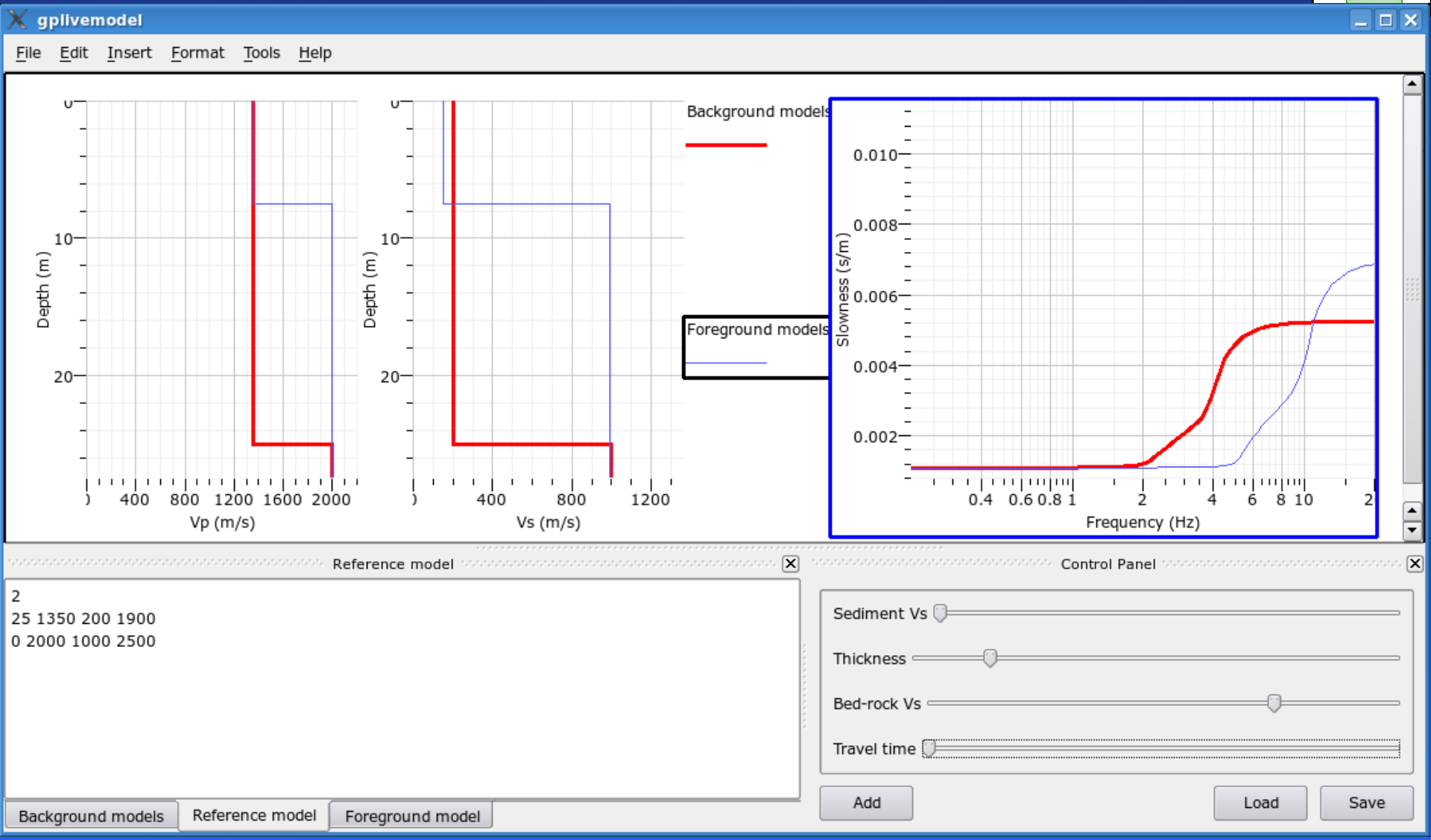
Gplivemodel : reference model



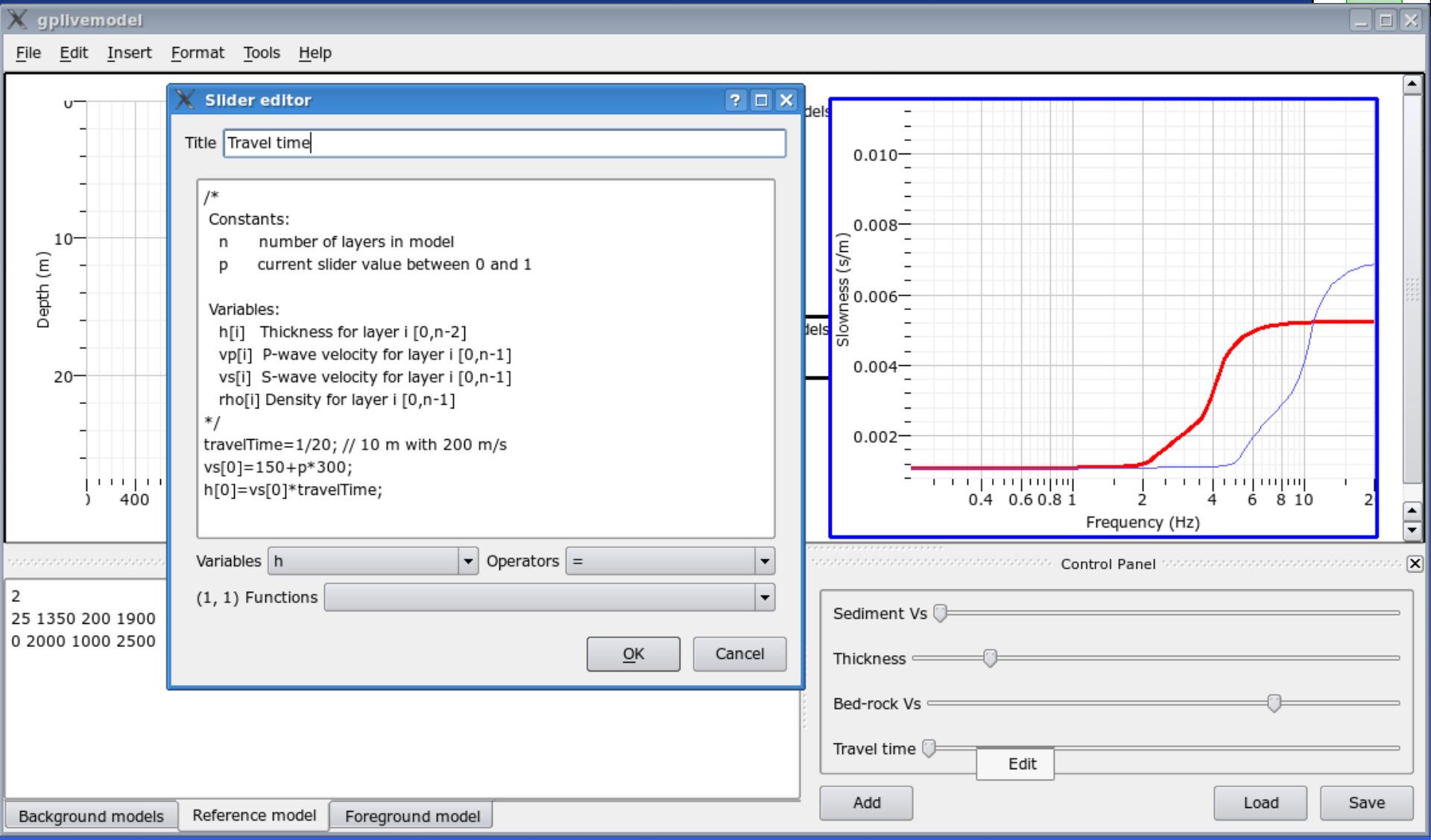
Gplivemodel : legends & control panel



Gplivemodel : play with cursors

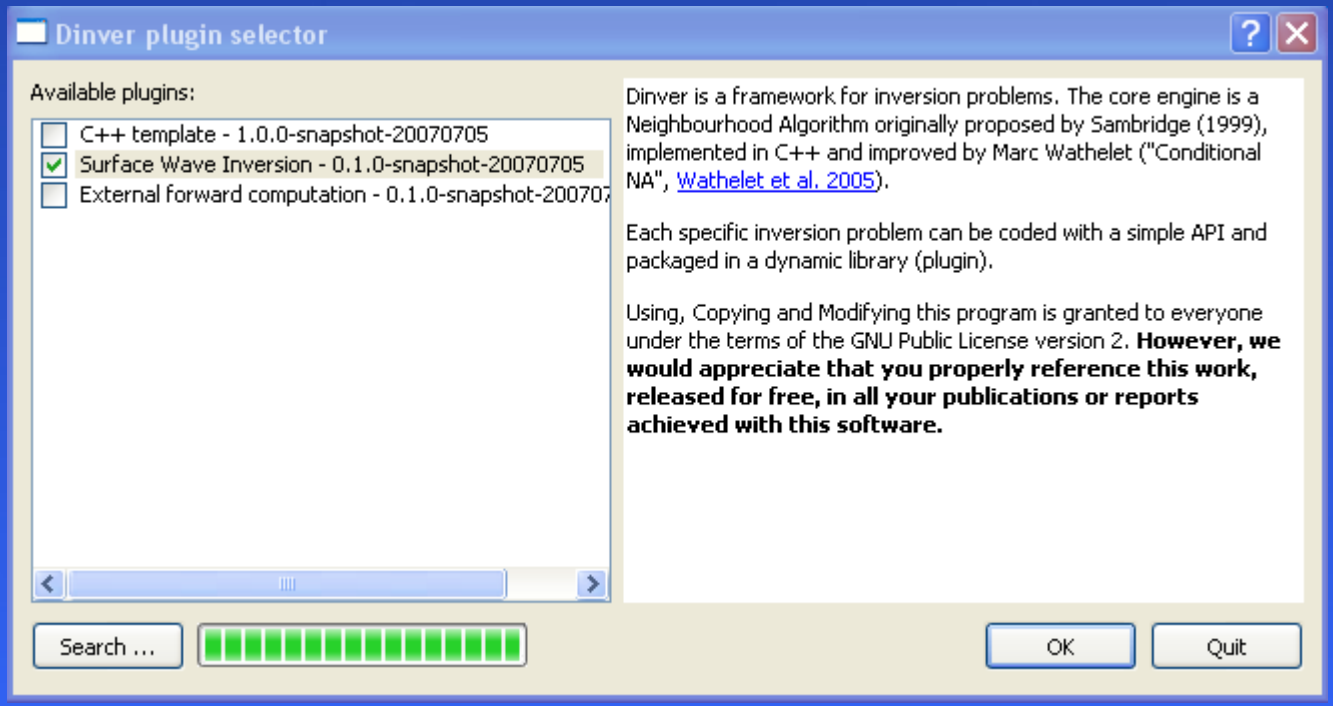


Gplivemodel : editing cursors

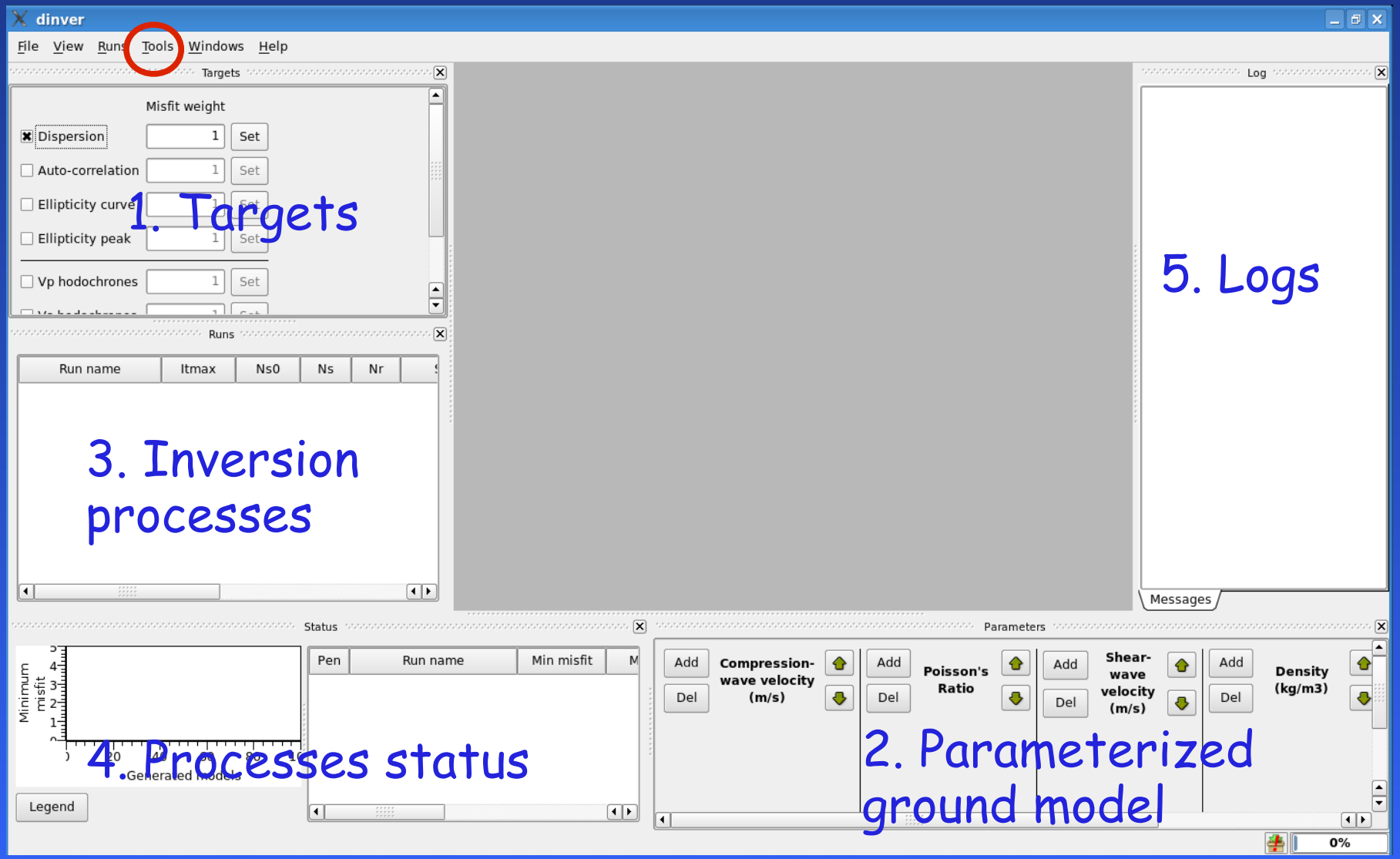


2. Inversion dispersion curves

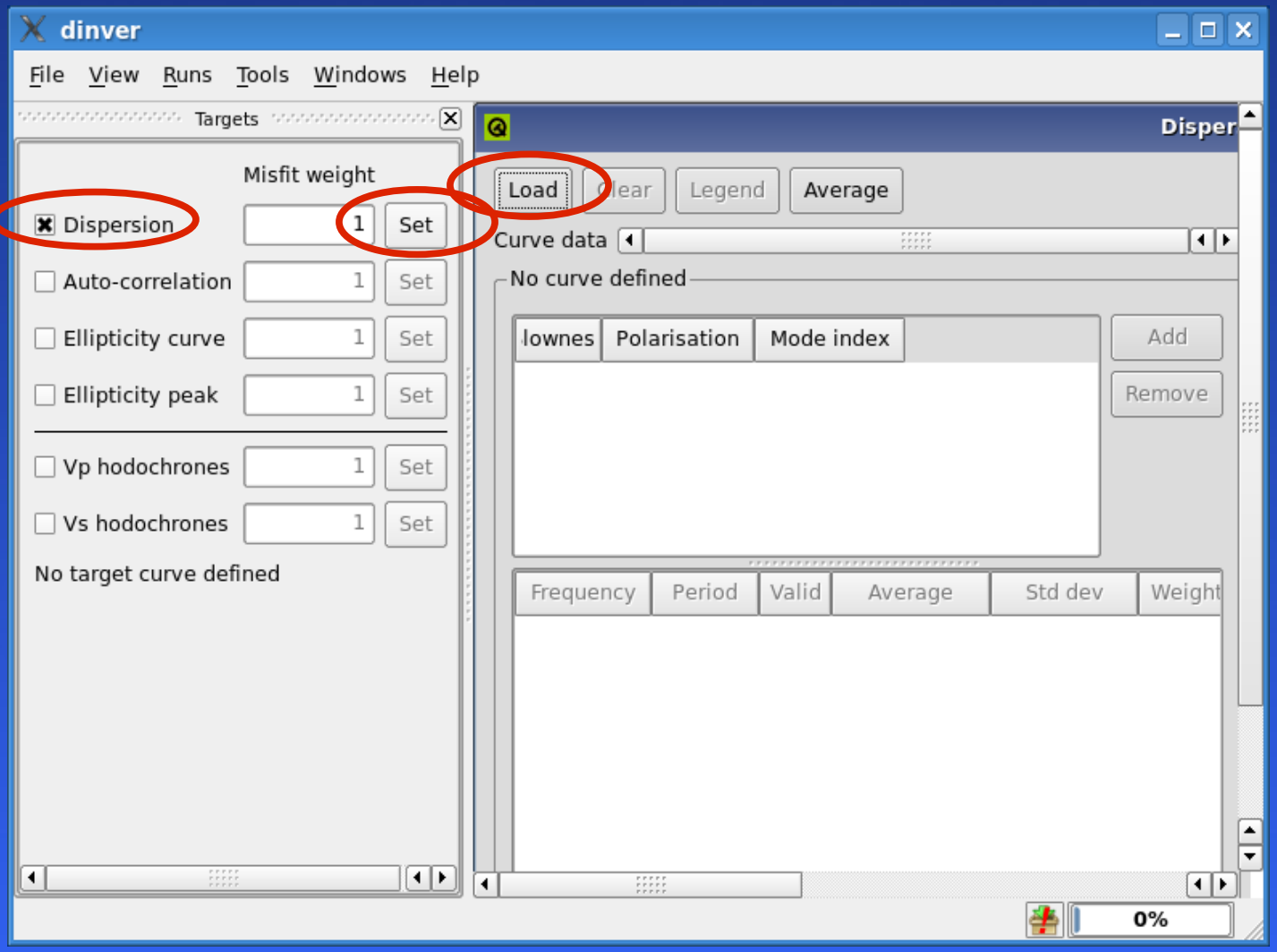
Starting Dinver: plugin selection



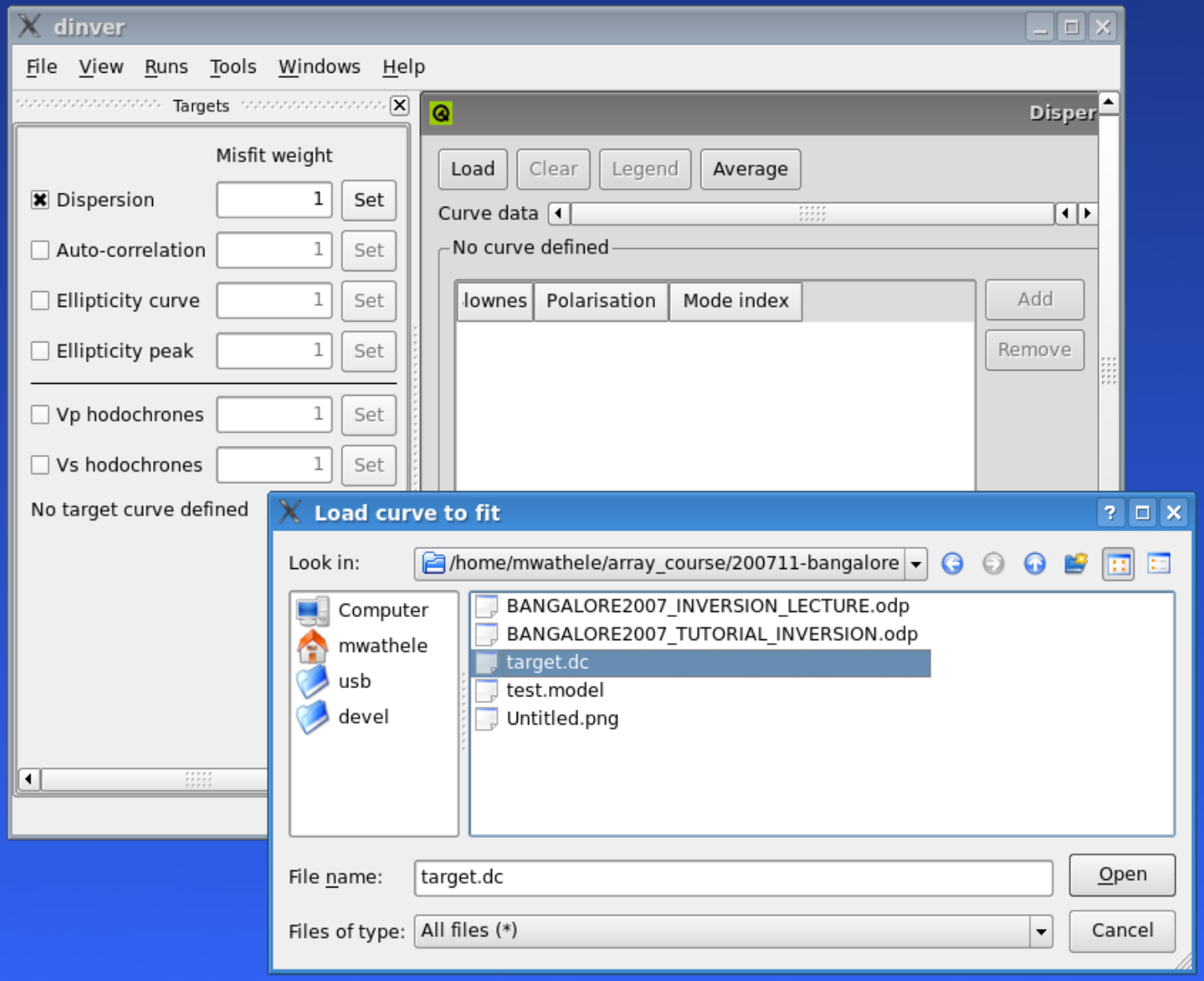
Surface Wave Inversion: Dinver's workspace



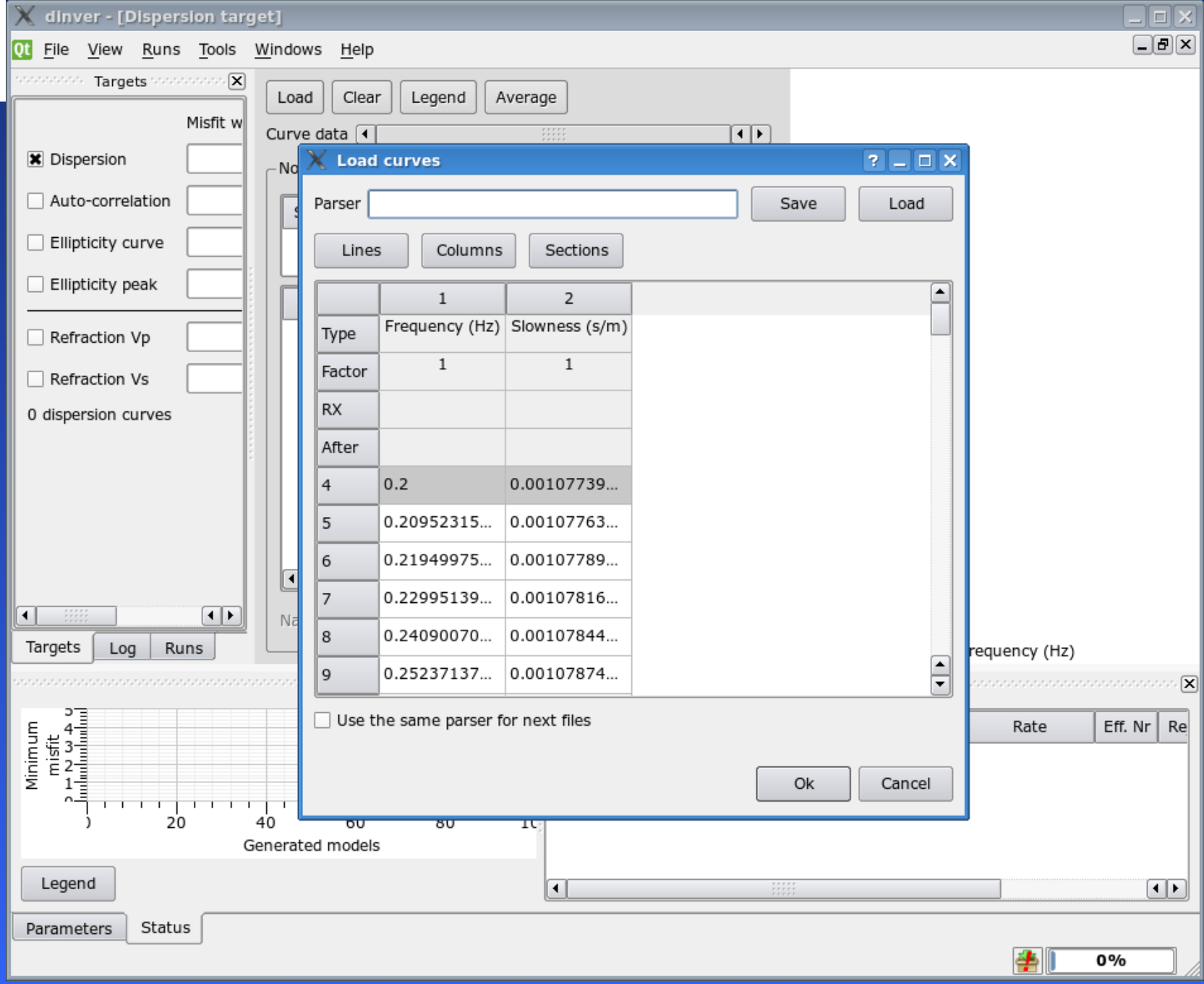
1. Selection of target curve



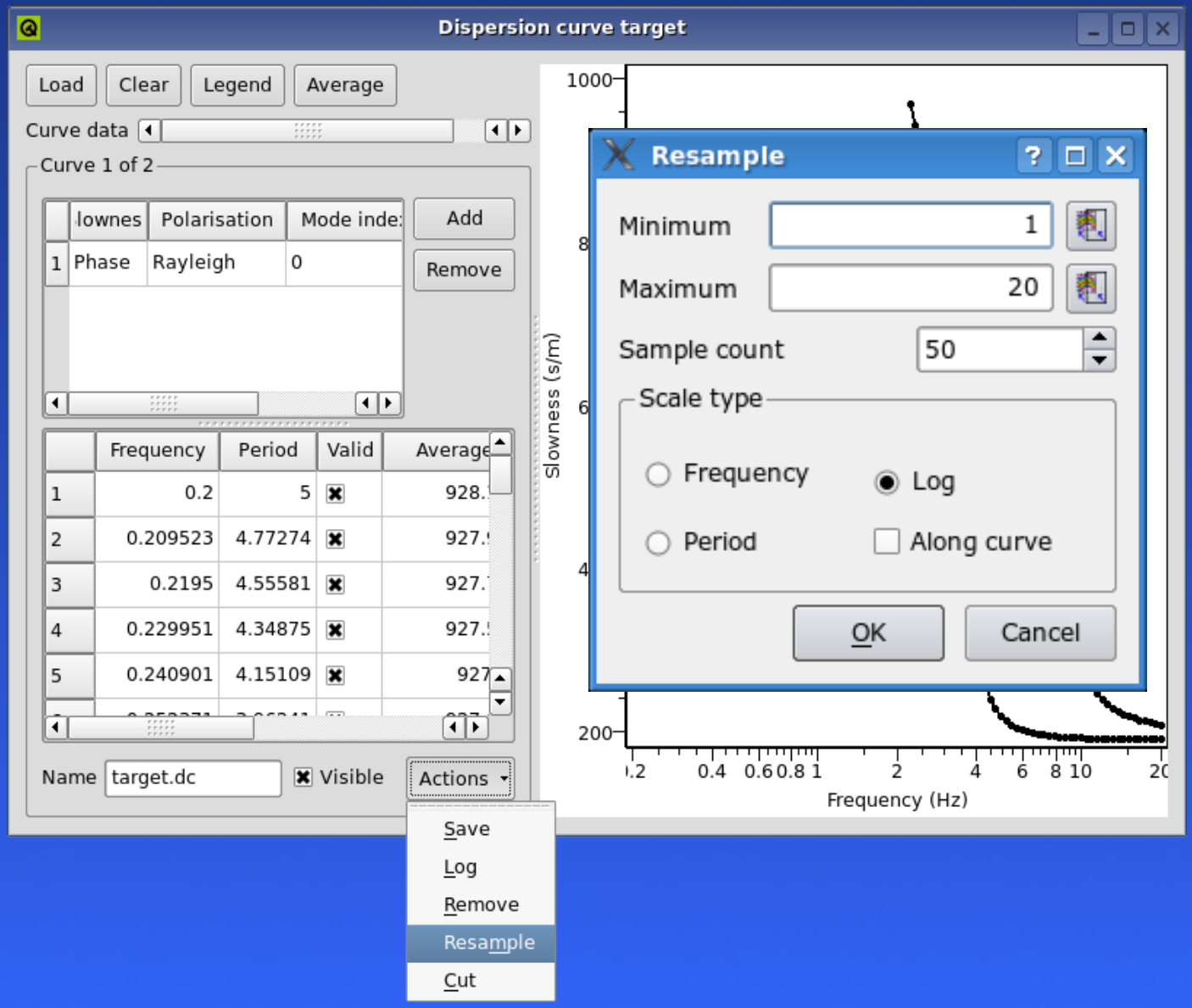
1. Selection of target curve



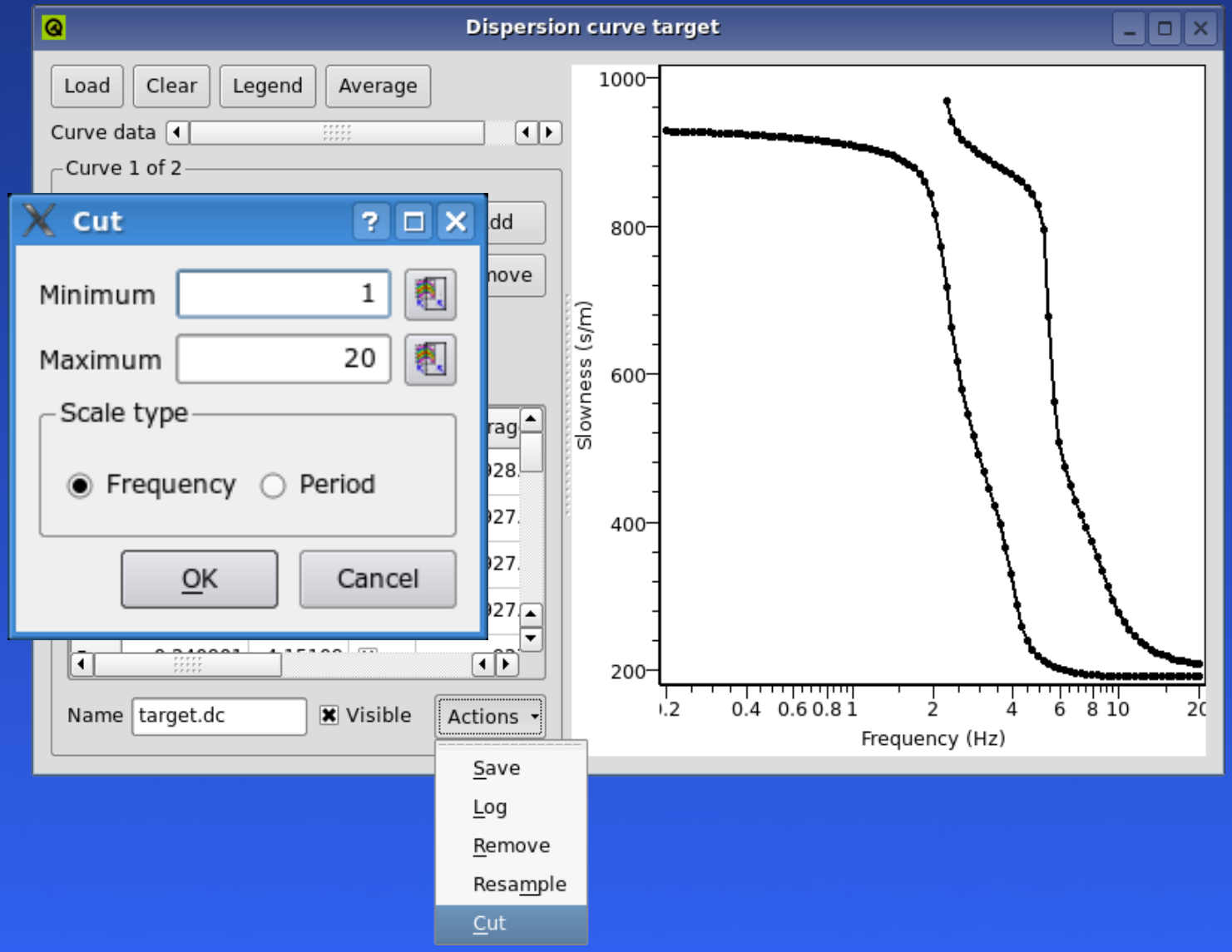
Import text file with dispersion curves



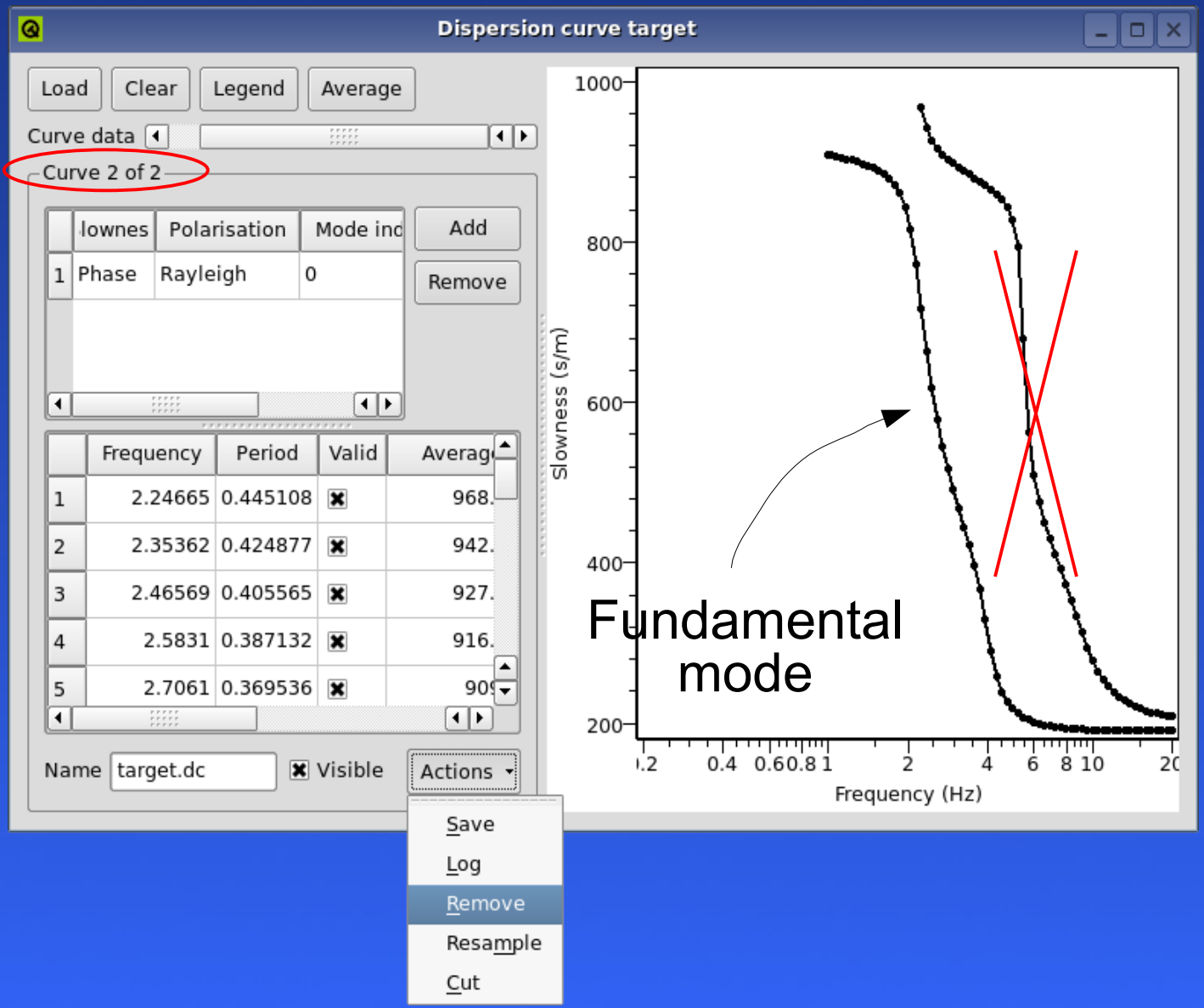
Resampling the target curve
Usually: between 30 to 50 samples



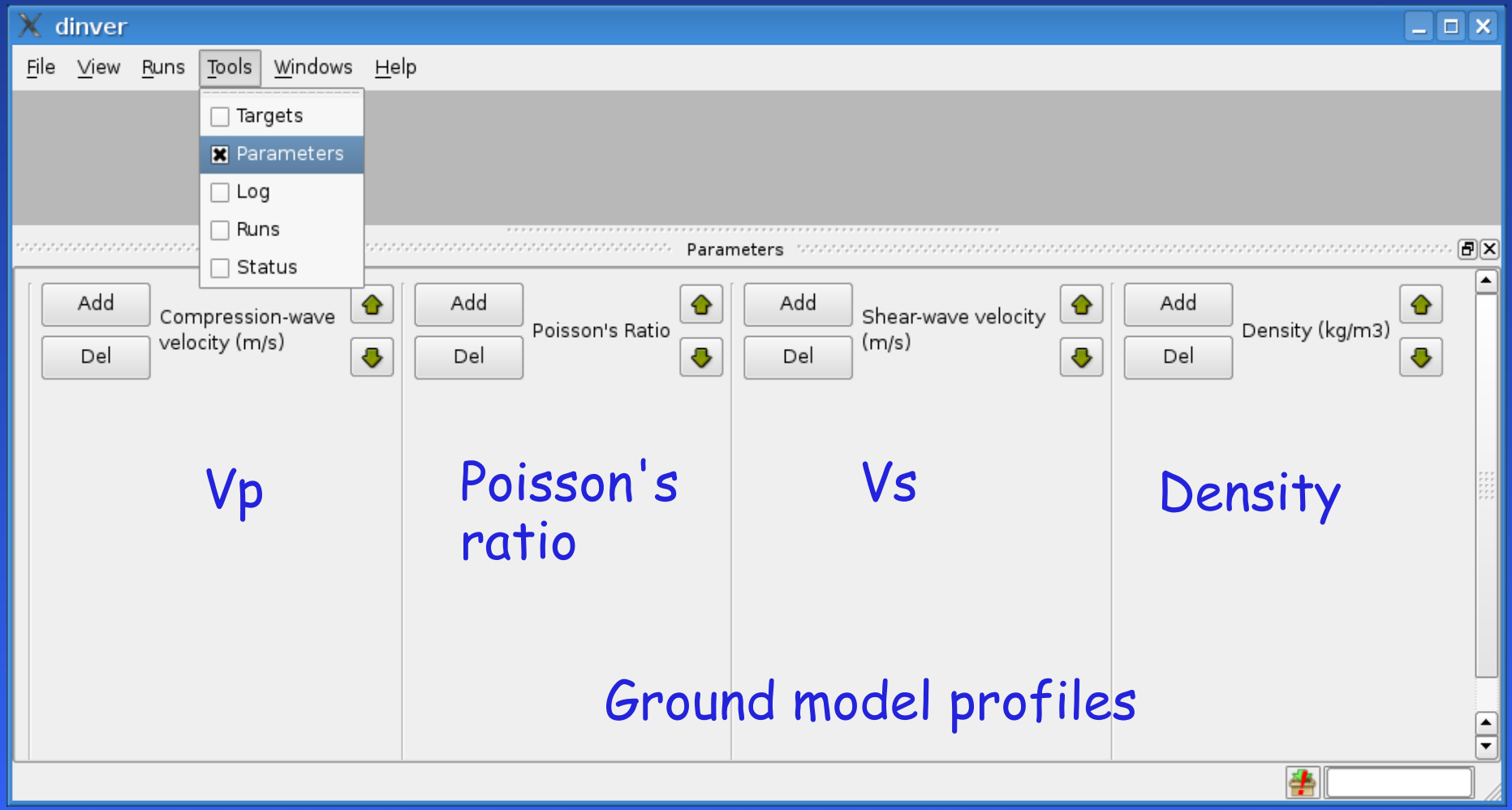
Cutting the target curve



All available curves are included in misfit
Remove the higher mode

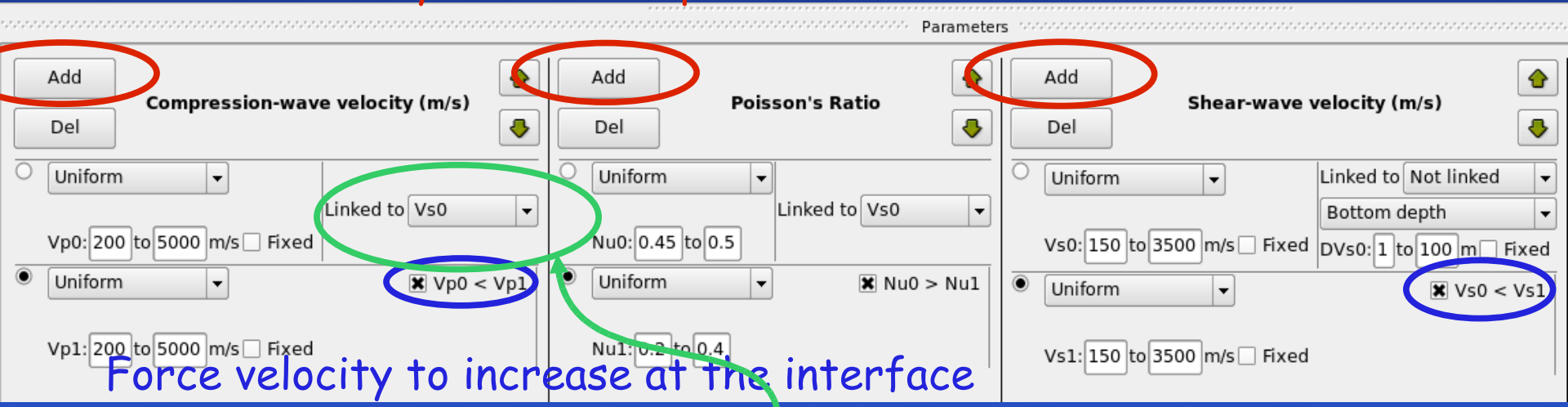


2. Definition of parameter space



Parameterized ground model with two layers and a positive velocity contrast

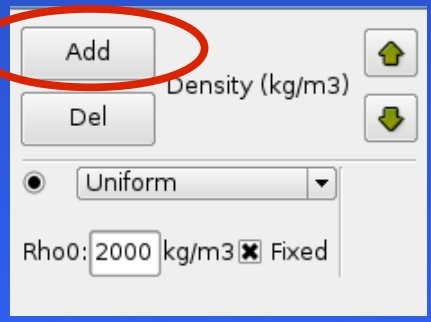
Add new layers to each profile



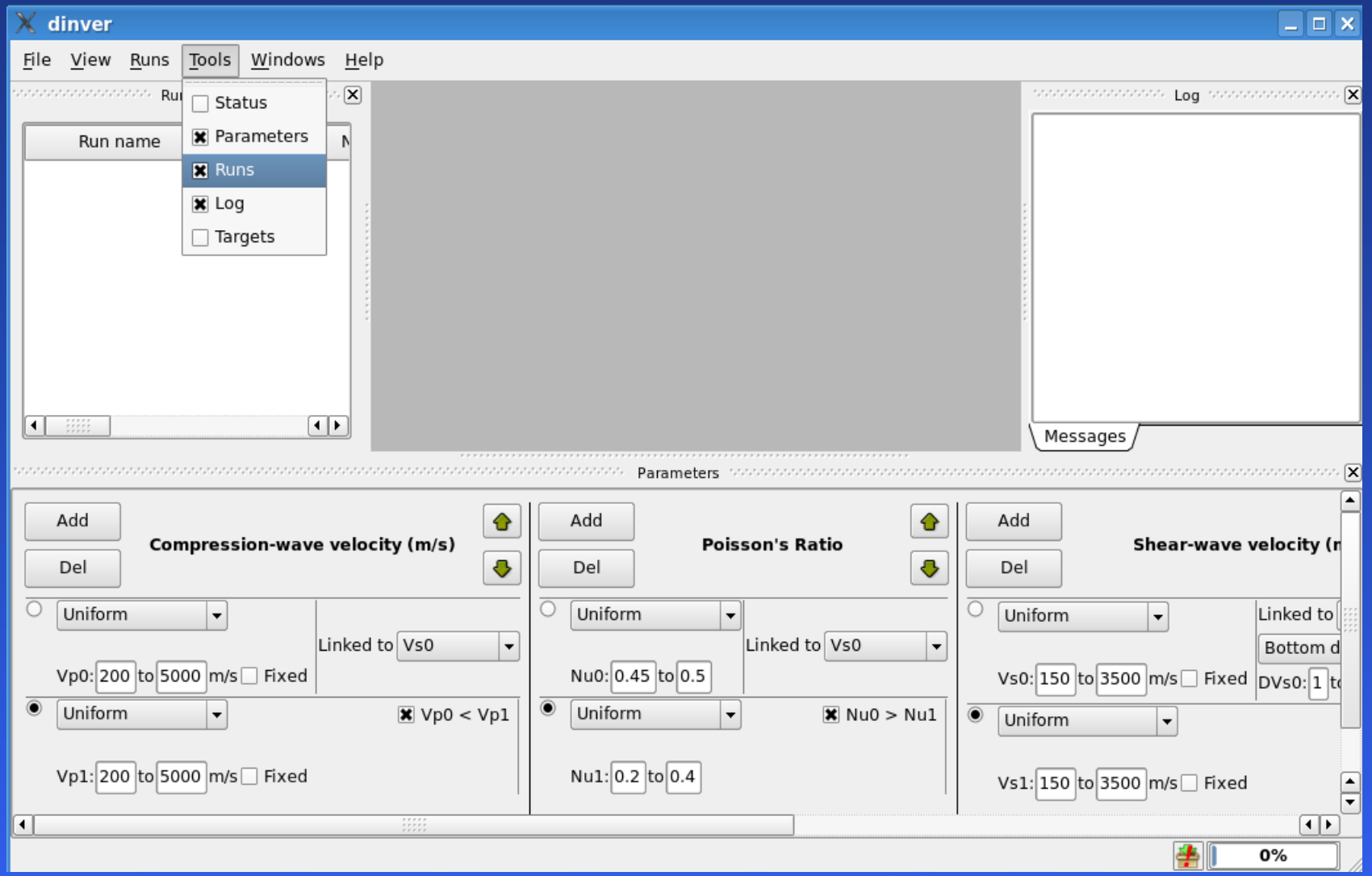
Force velocity to increase at the interface

Force Vp, Poisson and Vs profiles to have a common interface

Density generally fixed to a constant

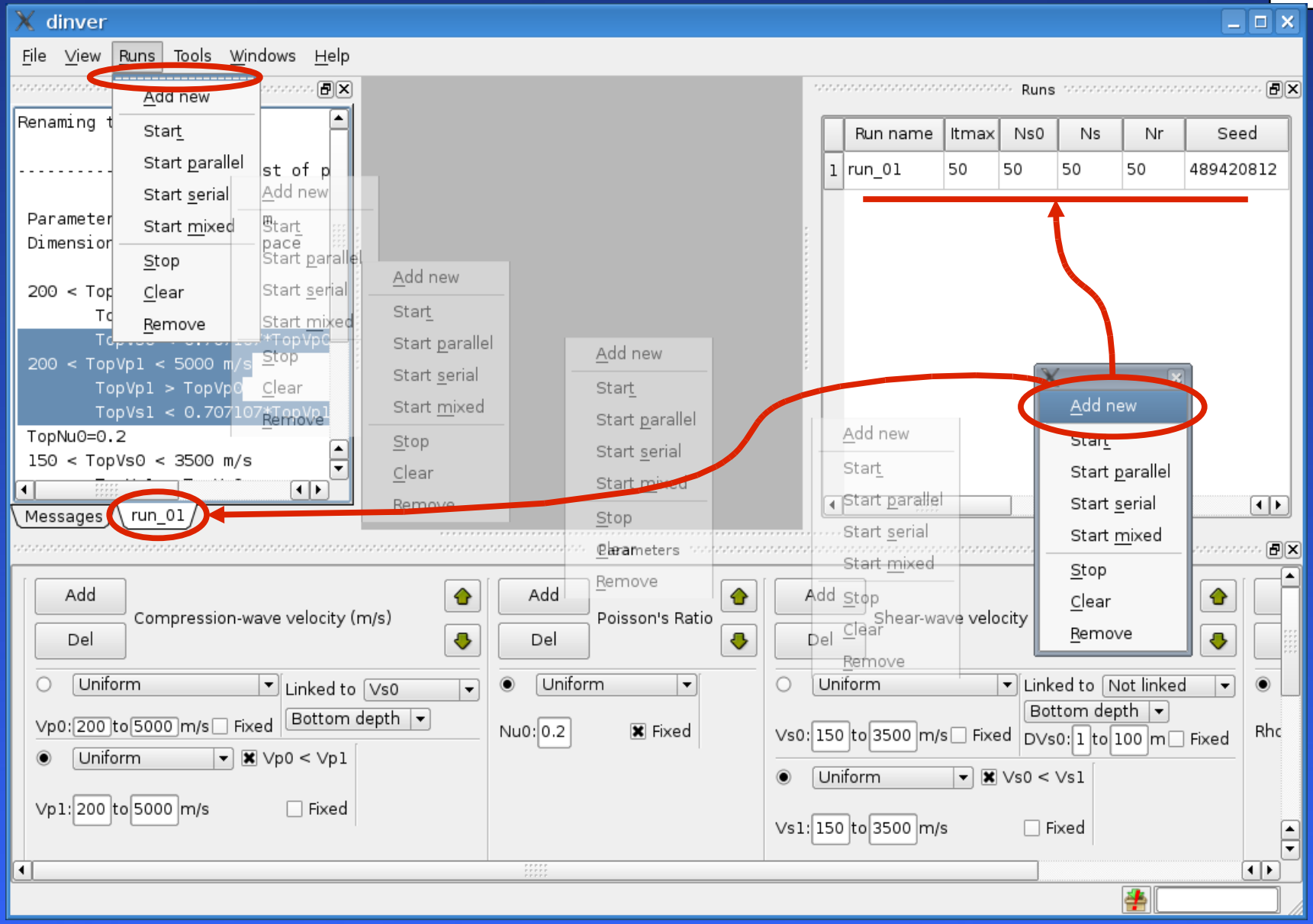


3. Create inversion processes

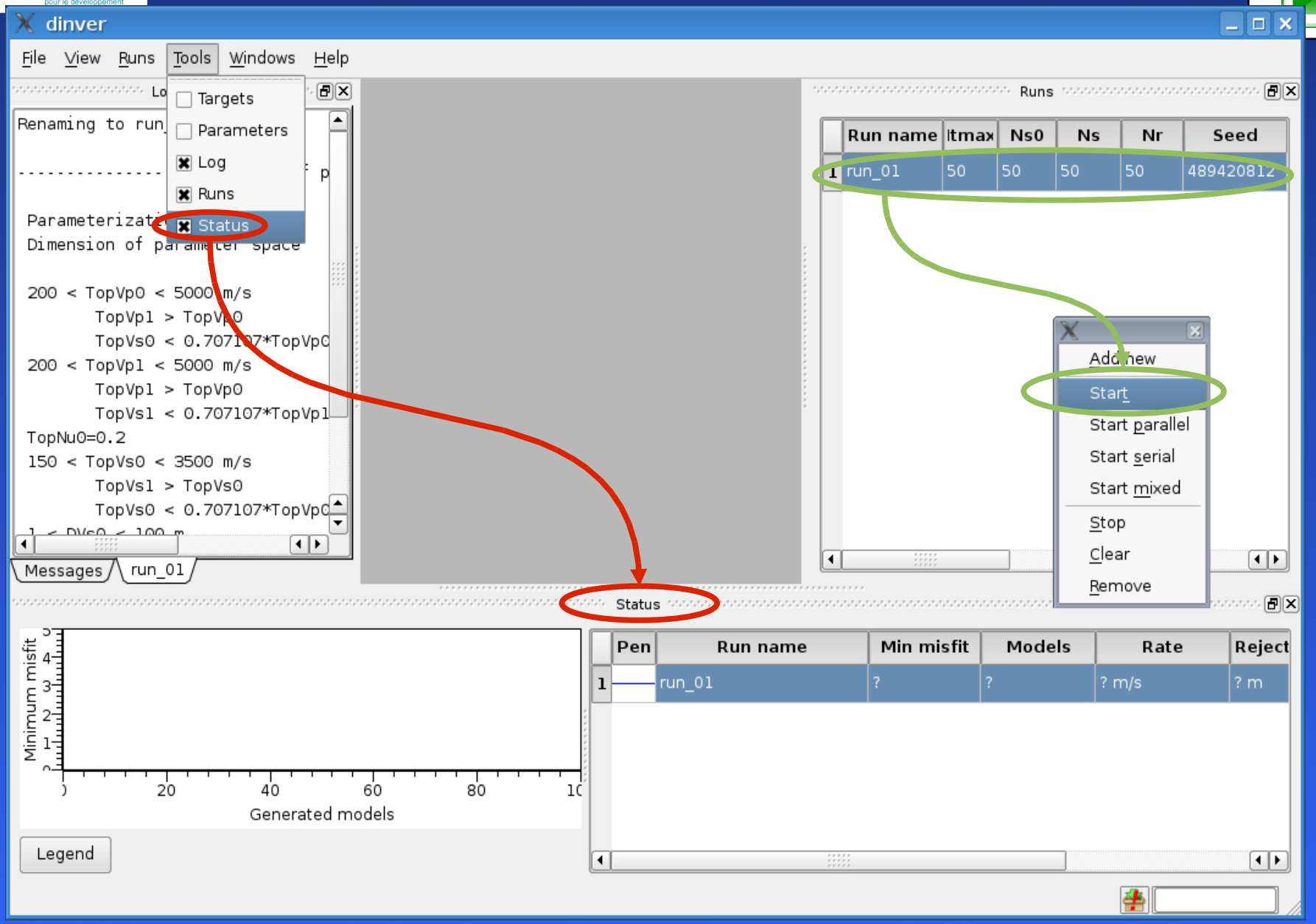


Show "Runs" & "Log" windows

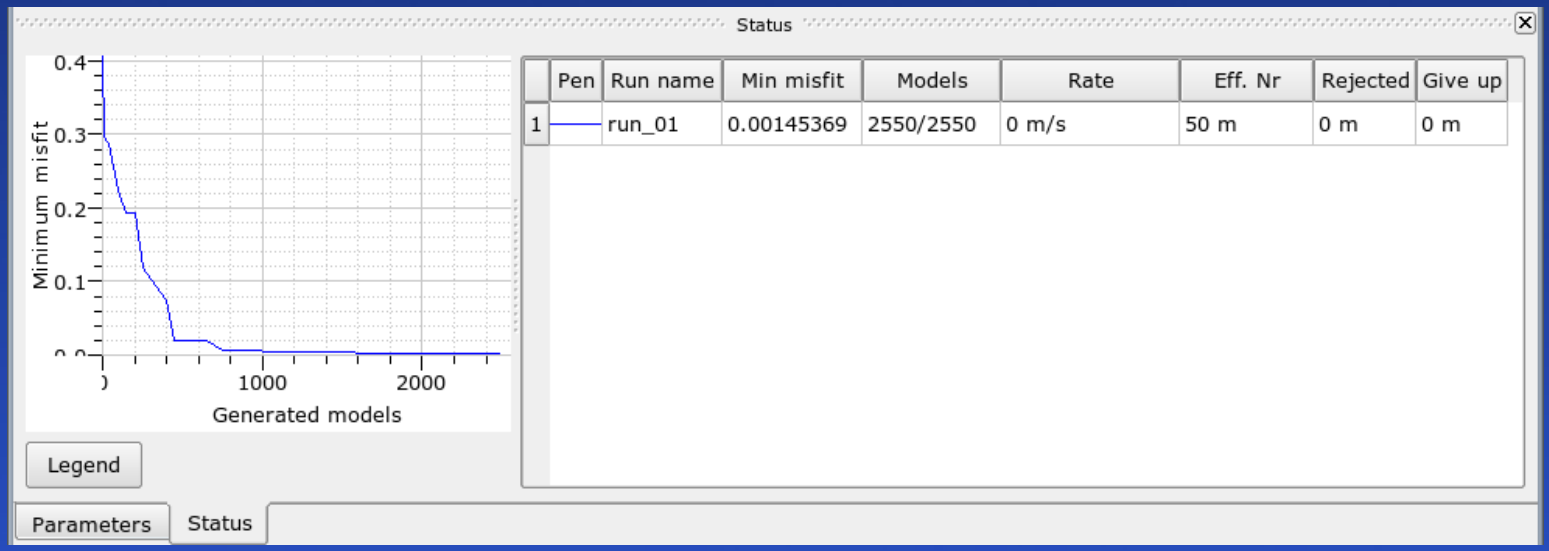
Add a new inversion run



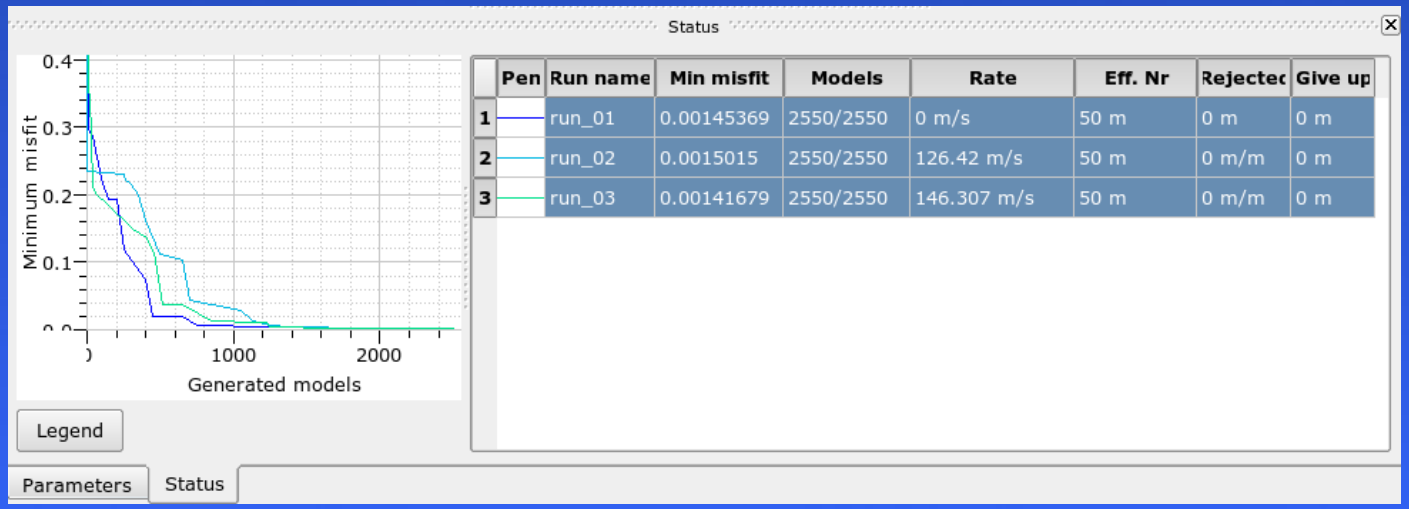
Start inversion run



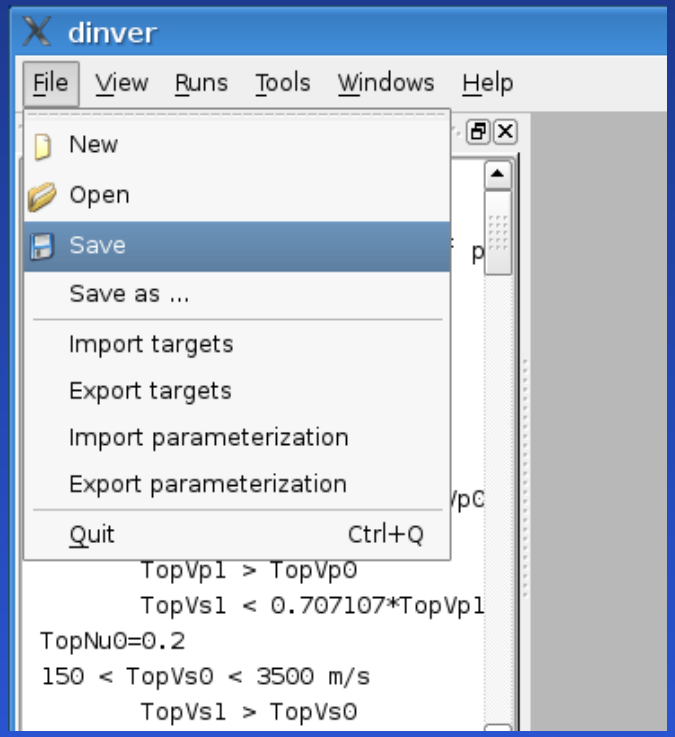
Misfit history & processes statistics



Start at least 2 or 3 runs with distinct seed values



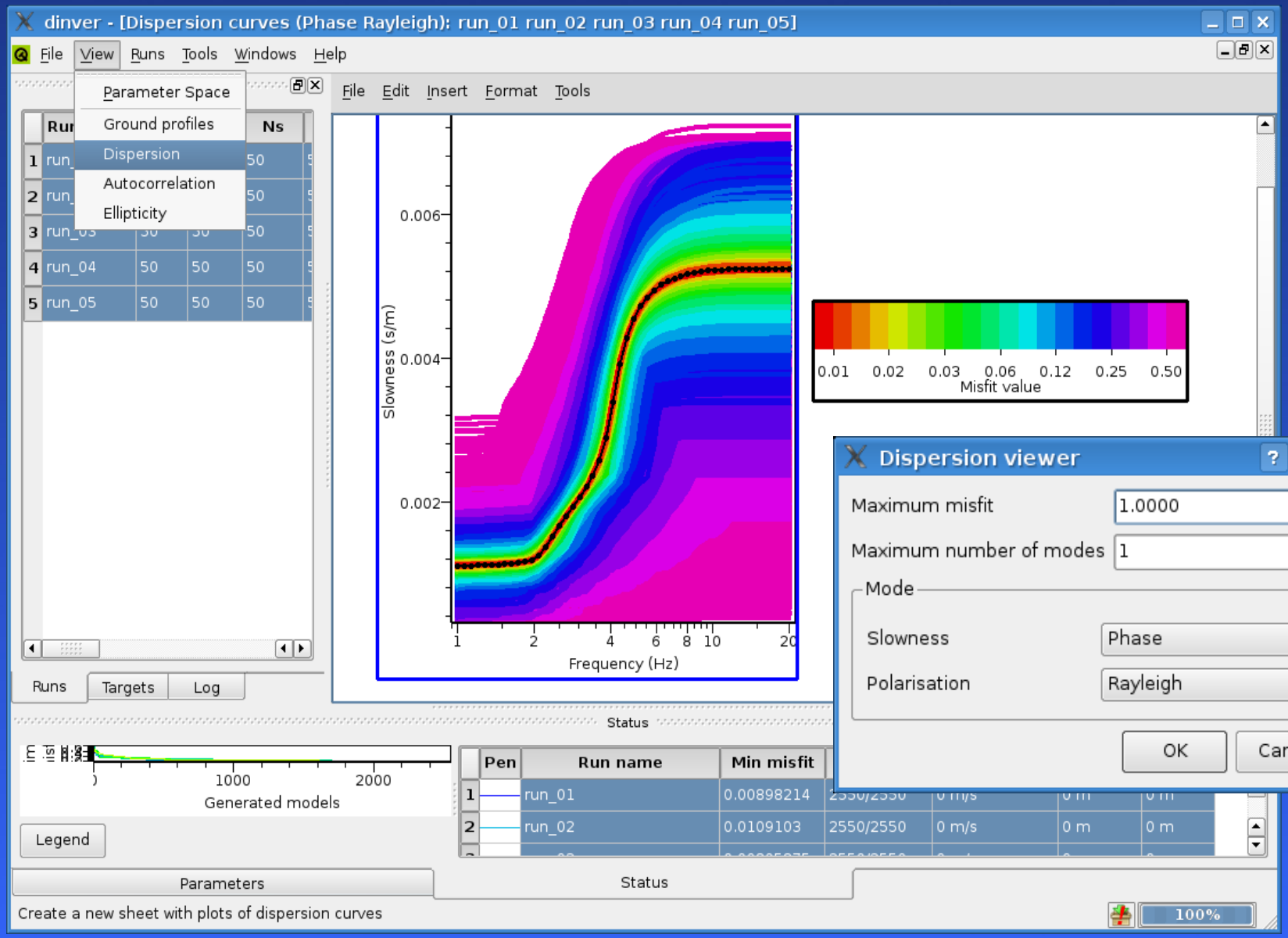
New/Open/Save a Dinver project



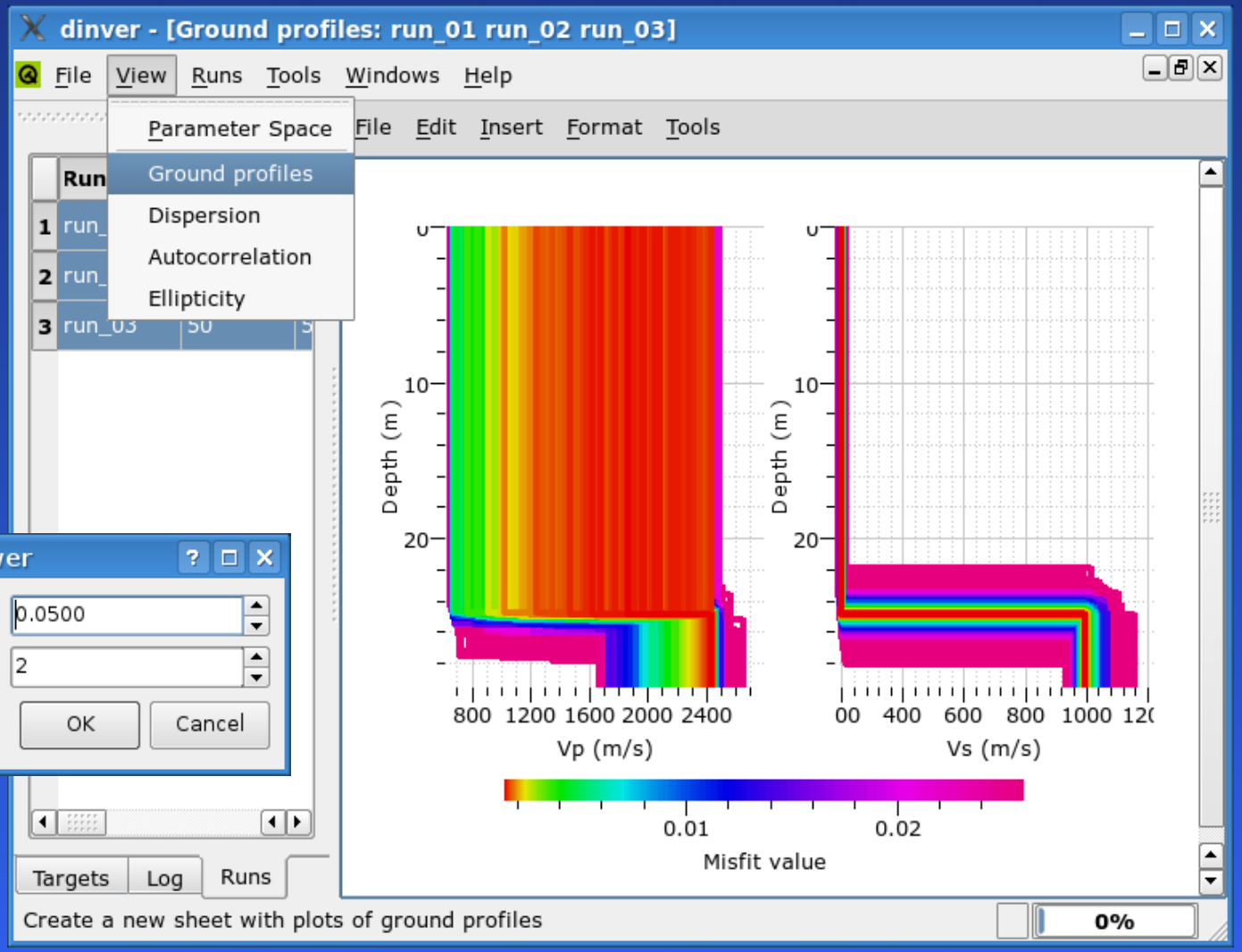
When no project is saved, all .report files are saved in **[YOUR HOME]/.dinvertemp/**

When project is saved, all .report files are saved in **[YOUR PROJECT]_report/**

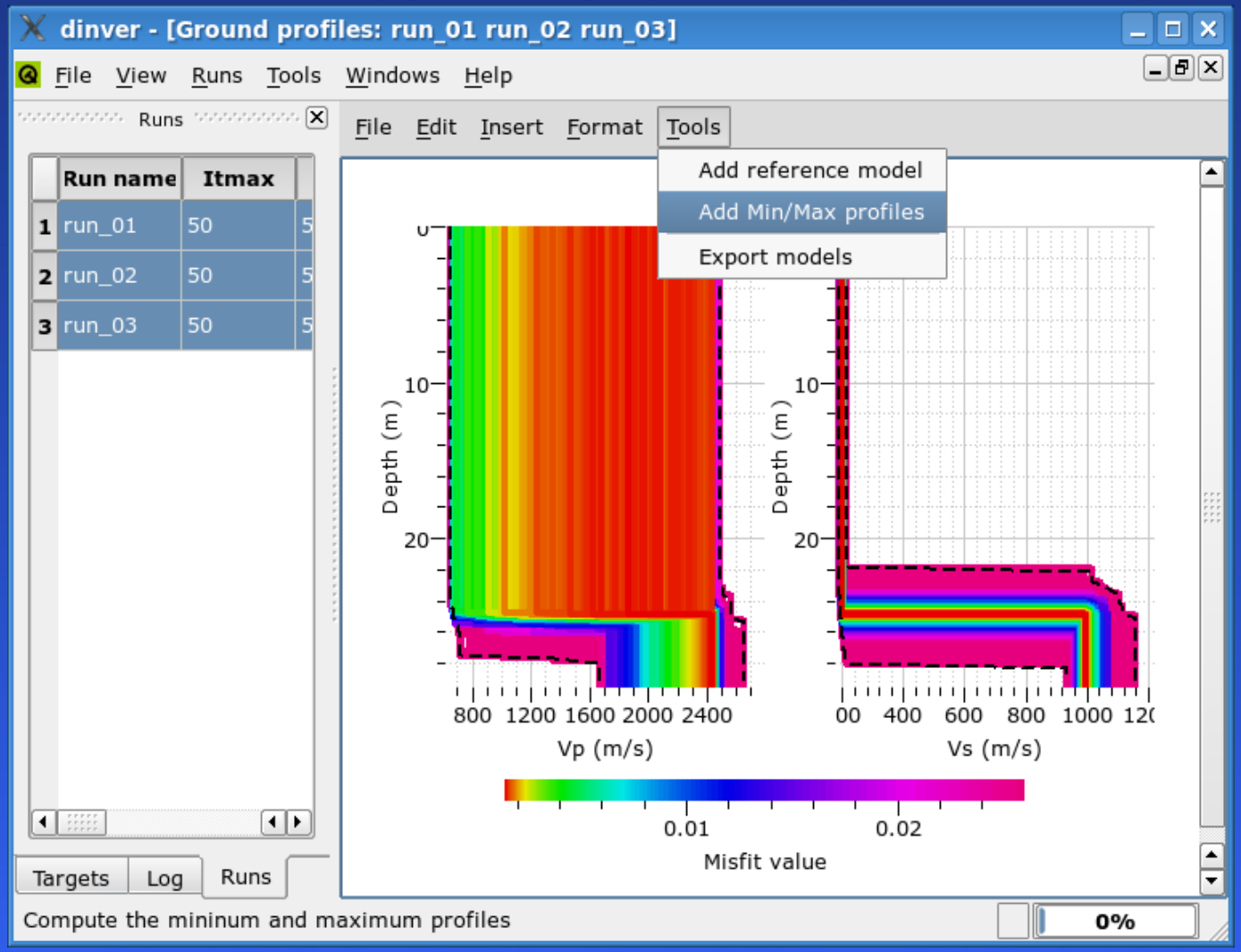
Viewing velocity profiles & dispersion curves



Viewing velocity profiles & dispersion curves



Calculating minimum and maximum profiles



Calculating minimum and maximum profiles

mwathele@sirac:~/.dinvertemp - Shell - Konsole

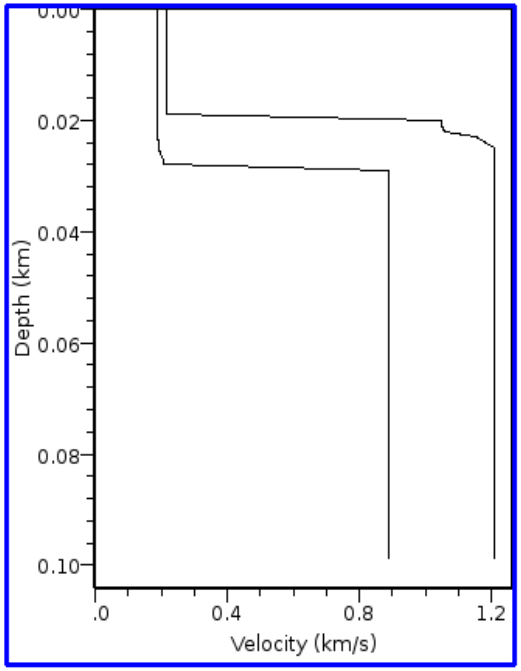
Session Edit View Bookmarks Settings Help

```
mwathele@sirac ~ $ cd ~/.dinvertemp/
mwathele@sirac ~/.dinvertemp $ ls
run_01.report  run_02.report  run_03.report  run_04.report  run_05.report
mwathele@sirac ~/.dinvertemp $ gpdcreport *.report -m 0.05 | gpprofile -minmax | figue -c -m ../data/INVERSION/vs.mkup
```

Shell

figue

File Edit Insert Format Help



dinver - [run_01]

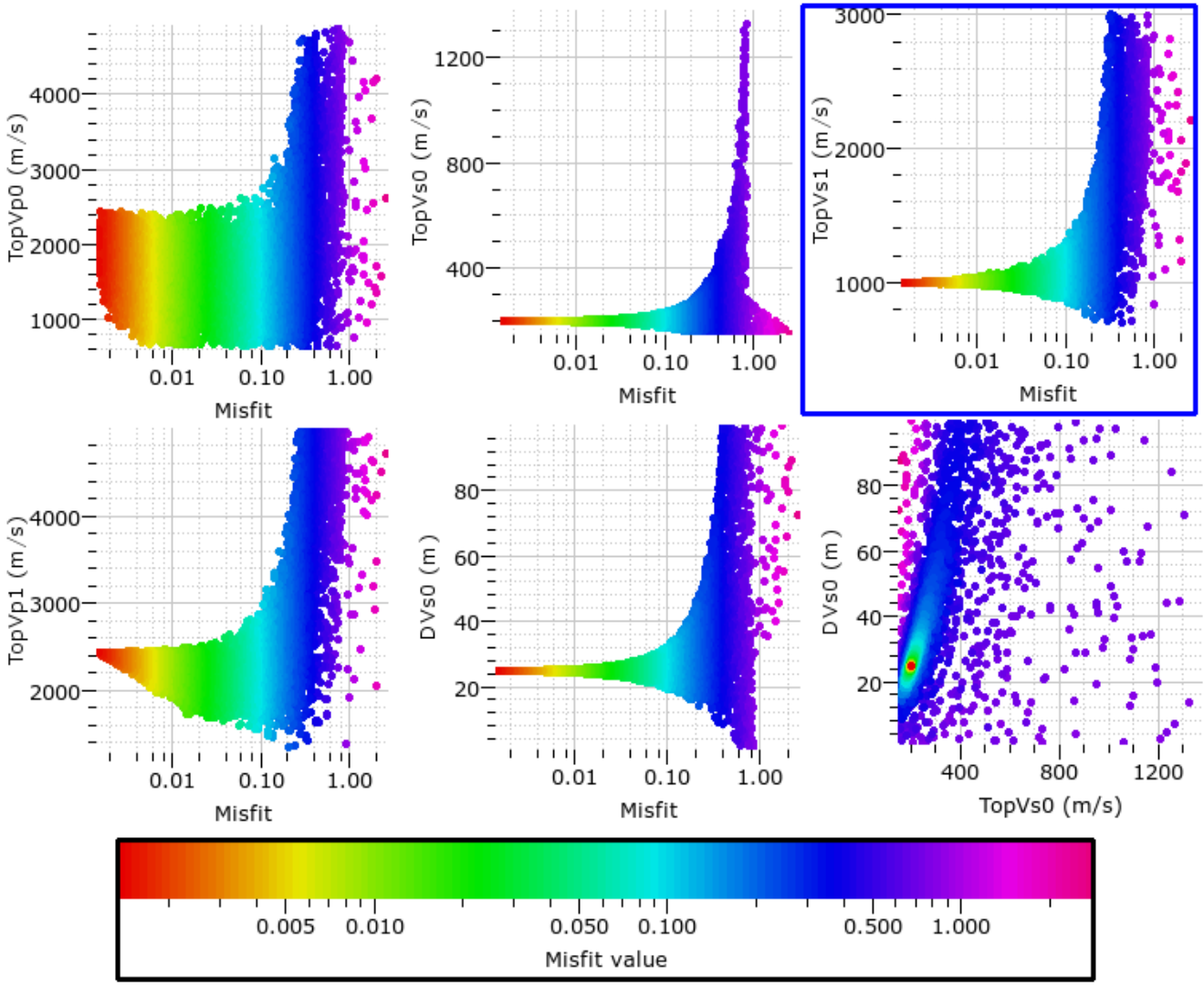
File View Runs Tools Windows Help

Runs

	Run name	Itmax	
1	run_01	50	5
2	run_02	50	5
3	run_03	50	5

Targets Log Runs

File Edit Insert Format



0%

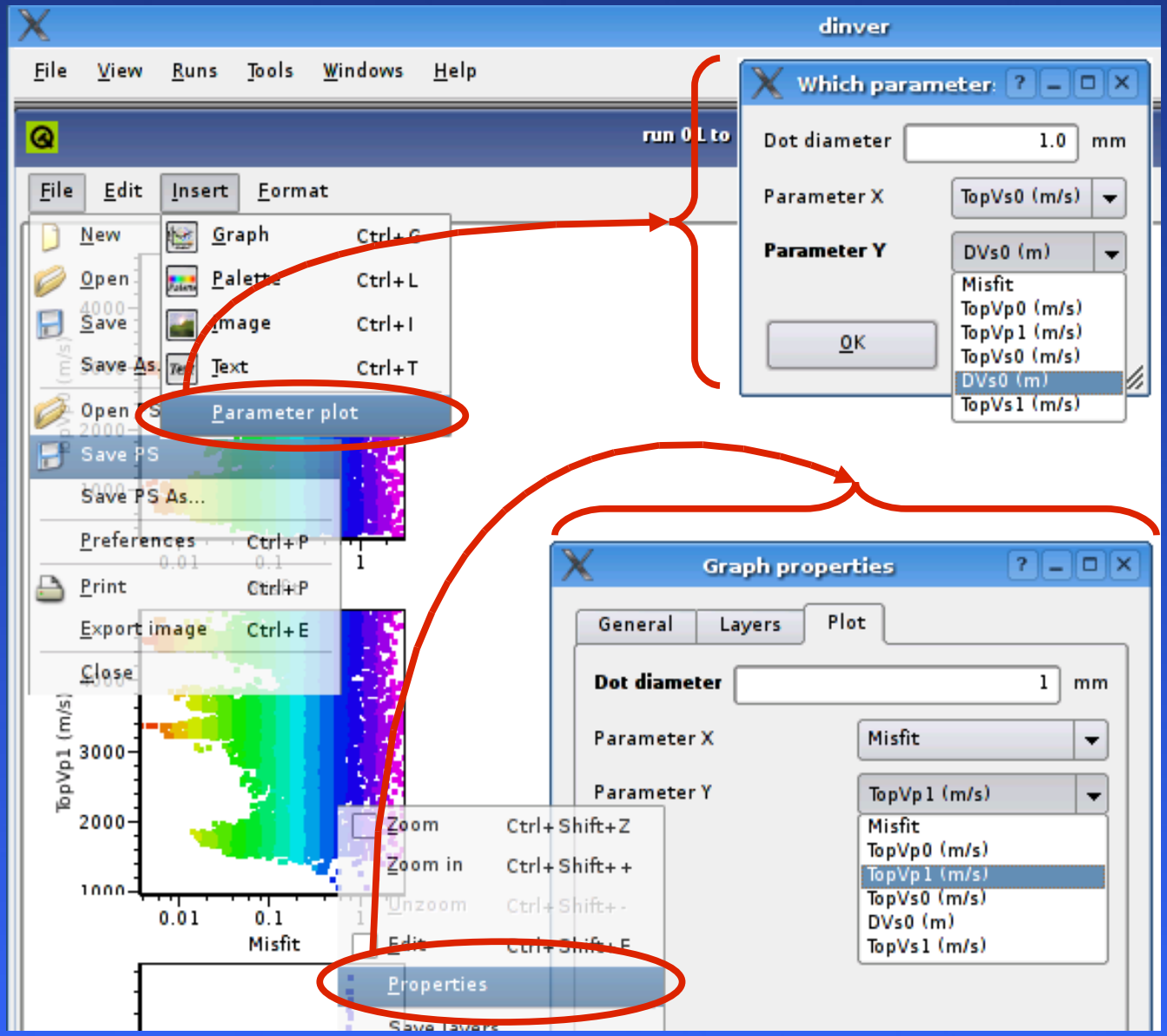
December 6th-12th, Thessaloniki, Greece

Parameter space viewer: 1D/2D projections

Basic output:
all parameters
vs misfit

Customization:
- Insert new plots
- change parameter for axis

Save/Open
PS viewer



Analysing .report files produced by inversion
Getting the very best model

mwathele@sirac:~/.dinvertemp - Shell No. 2 - Konsole

Session Edit View Bookmarks Settings Help

```
mwathele@sirac ~ $ cd ~/.dinvertemp
mwathele@sirac ~/.dinvertemp $ gpdcreport *.report -m 0.0065
# Report = run_01.report
# N Models = 2550
# Report = run_02.report
# N Models = 2550
# Layered model 2213: misfit=0.006443
2
    24.9084257956825     1538.56959606898      198.84757010434                2000
                   0     3296.21090054071     985.707783525062                2000
# Report = run_03.report
# N Models = 2550
# Report = run_04.report
# N Models = 2550
# Report = run_05.report
# N Models = 2550
# Layered model 2368: misfit=0.005380
2
    25.0600443585102     3261.77736624921      200.935389014041               2000
                   0      3901.0551582349      979.250539654446               2000
mwathele@sirac ~/.dinvertemp $
```

Shell | Shell No. 2

Effects of CNA tuning parameters

Itmax: Number of iterations required

Ns0: Initial set of random models

Ns: Number of models generated at each iteration

Nr: Number of "best" cells selected for generation of Ns models

Seed: Any integer number

DynScale: Yes = better exploration

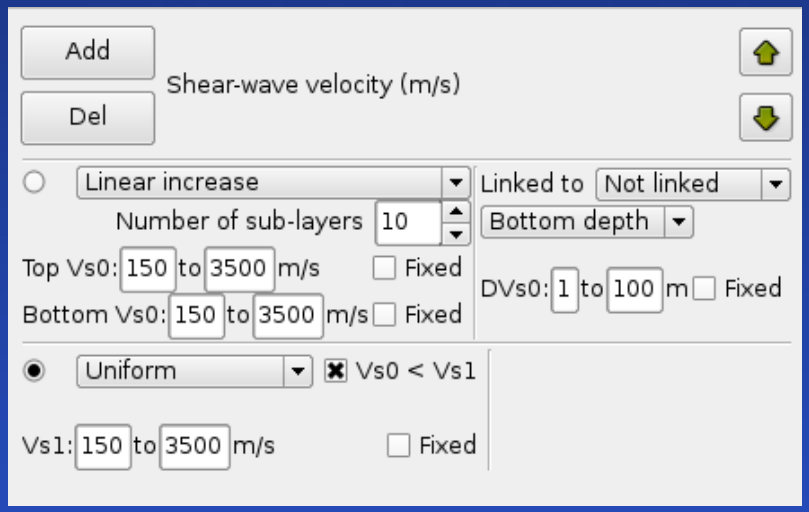
Nw: Number of random walk (Markov chain)

GiveUp: Maximum ratio of rejected/accepted model

Effects of CNA tuning parameters

Behavior	Itmax	Ns0	Ns	Nr
Monte Carlo	0	10000	-	-
Exploration	100	100	100	100
	200	50	50	50
	100	100	100	50
	100	100	100	10
Optimisation	100	100	100	1

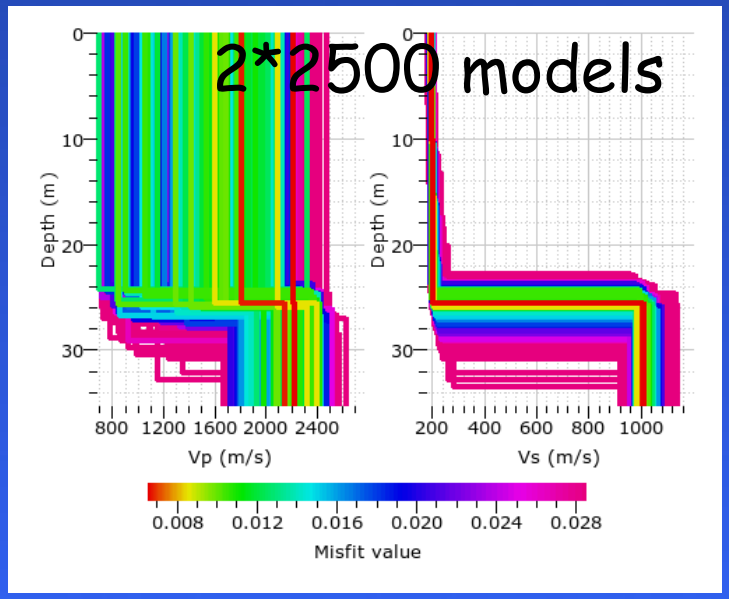
Two layers with a gradient

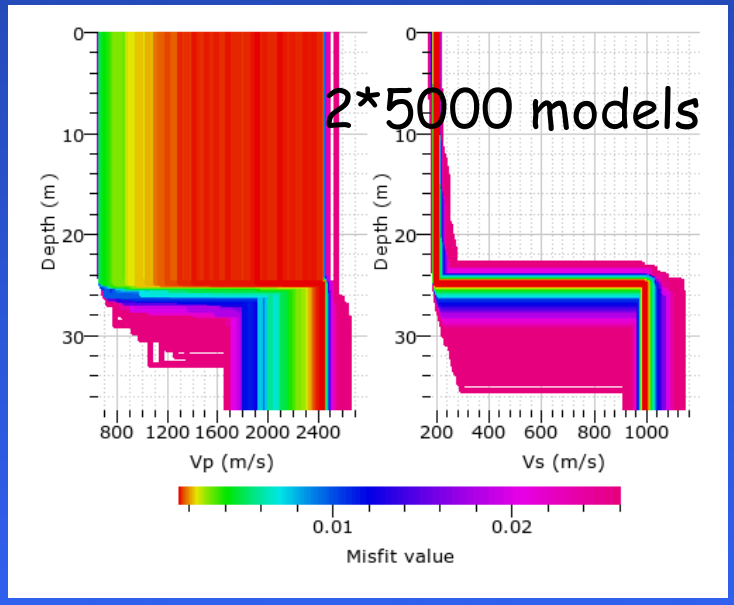


Run 3 runs with 2500 models

View ground models with a misfit < 0.05

What's different?





One more layer

Parameters

Add / Del

Compression-wave velocity (m/s)

Uniform — Linked to Vs1

Vp0: 200 to 5000 m/s Fixed

Uniform — Vp0 < Vp1

Vp1: 200 to 5000 m/s Fixed

Add / Del

Poisson's Ratio

Uniform — Linked to Vs1

Nu0: 0.45 to 0.5

Uniform — Nu0 > Nu1

Nu1: 0.2 to 0.4

Add / Del

Shear-wave velocity (m/s)

Linear increase — Linked to Not linked

Number of sub-layers 5

Top Vs0: 150 to 3500 m/s Fixed — Bottom depth

Bottom Vs0: 150 to 3500 m/s Fixed — DVs0: 1 to 100 m Fixed

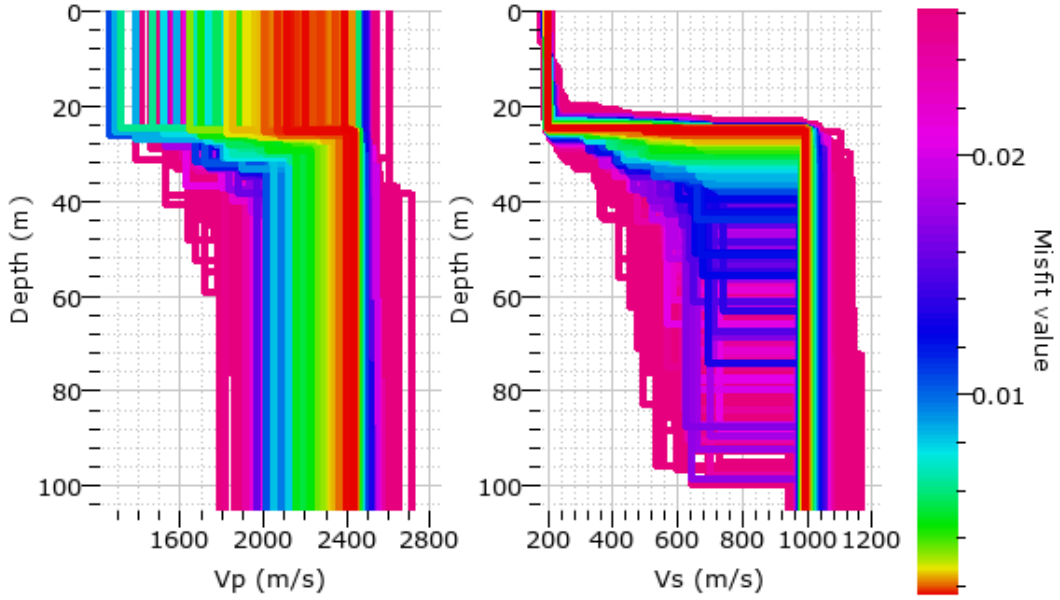
Uniform — Vs0 < Vs1 — Linked to Not linked

Vs1: 150 to 3500 m/s Fixed — Bottom depth

DVs1: 1 to 100 m Fixed

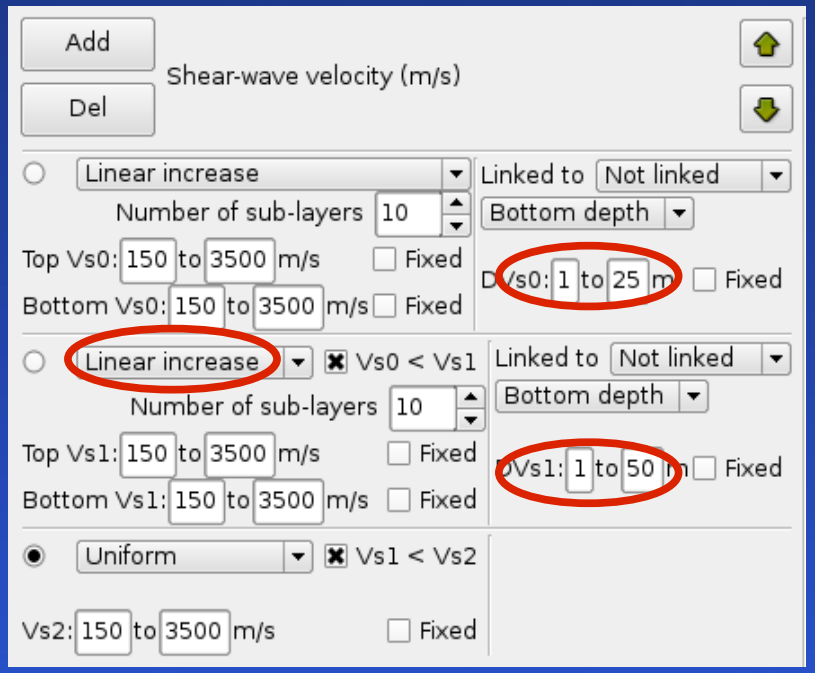
Uniform — Vs1 < Vs2

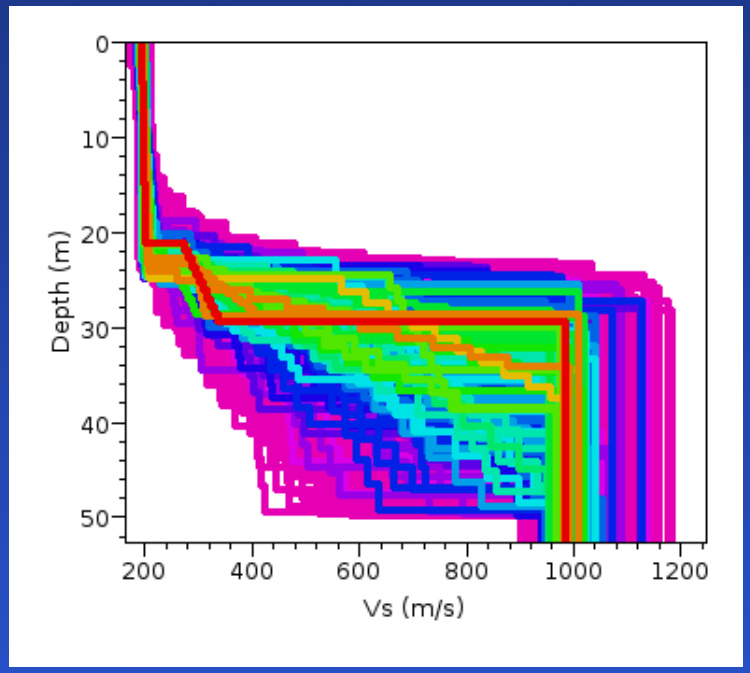
Vs2: 150 to 3500 m/s Fixed



2*7650 models

Force a supplementary layer in sediments





Analysing .report files produced by inversion
Computing ellipticity for the best models

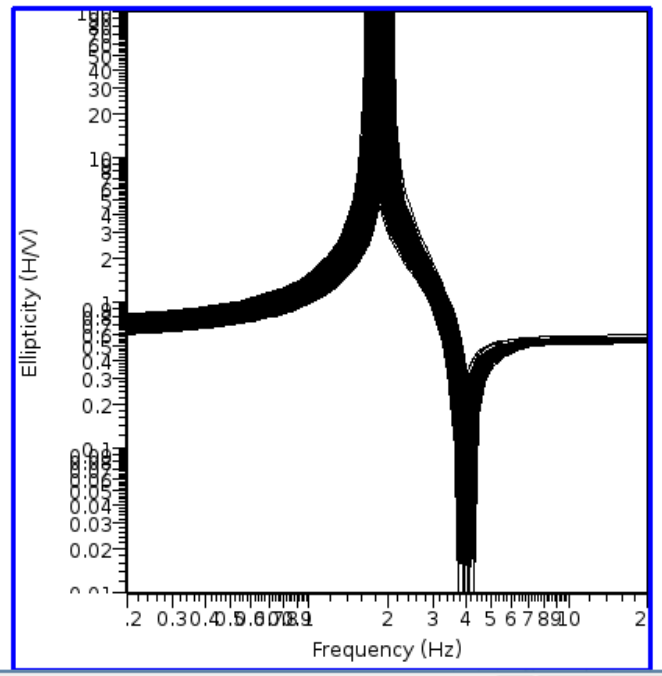
mwathele@sirac:~/.dinvertemp - Shell - Konsole

Session Edit View Bookmarks Settings Help

```
mwathele@sirac ~ $ cd ~/.dinvertemp/
mwathele@sirac ~/.dinvertemp $ ls
run_01.report  run_02.report  run_03.report  run_04.report  run_05.report
mwathele@sirac ~/.dinvertemp $ gpdcreport *.report -m 0.05 | gpell | figue -c -m ../data/INVERSION/ell.mkup
```

figue

File Edit Insert Format Help



Command line tools

From a model file

gpdc : dispersion curves (Rayleigh, Love, Group)
gpell : ellipticity curves
gpprofiles : Vp, Vs, Poisson profiles
gpspac : spac curves
gpec8 : Eurocode site classes
gpsh : Sh transfer function (coming soon...)

Inversion report post-processing

gpdcreport : any extraction of information
gpdcmisfit : re-computation of misfit
gpviewdcreport : direct access to model plot

Misc.:

gppoisson, gpparam2model, gpmodel2param, gpgroup2phase, gpcurve

A slightly more complicated inversion problem

`Files in EXERCISES_INVERSION/ibt_dataset_synthetic`

All curves provided in this test are not real nor simulated.
There are just theoretical curves with some manually added noise.

We provide you with 3 branches of dispersion curves, two pseudo-obtained from a array FK processing (dc1 and dc2) and a third one acquired with an active sourceexperiment with burried explosive sources.

You'll also find a pseudo H/V curve (pseudo obtained with classical processing). hv_average is the average curve and hv_low and hv_high are the one standard deviation curves.

Finally, you have spac curve from 5 rings: 10-12m, 23-27m, 35-41m, 46-57m and 67-88m.

Good luck!