UNIVERSITÀ
DEGLI STUDI DI TRIESTE

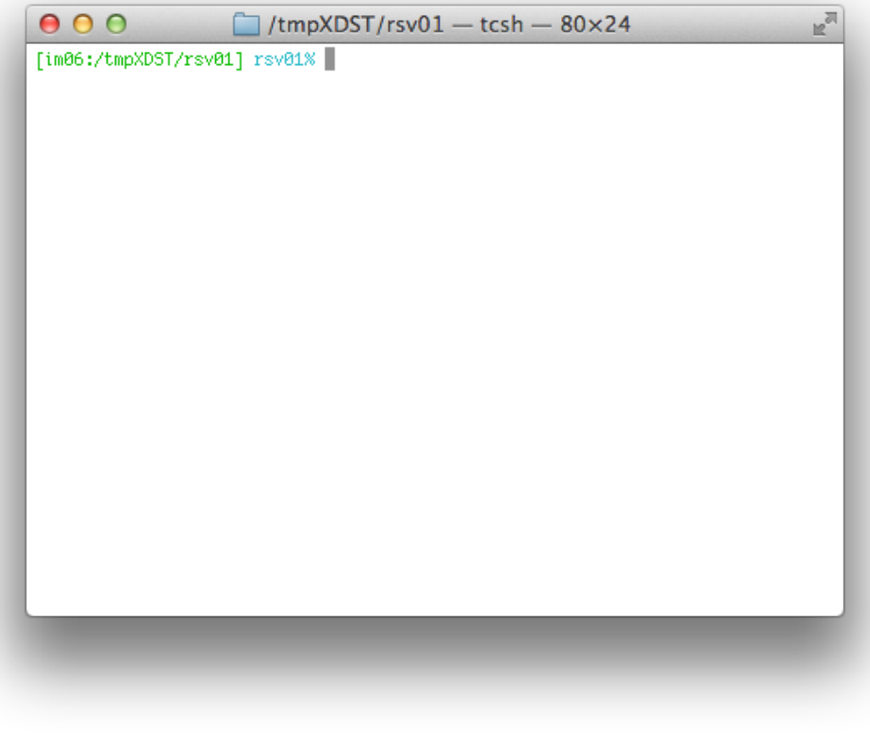
# Seismic Hazard Computer Exercises

Franco Vaccari

Corso di Rischio Sismico e Vulcanico - Esercitazioni

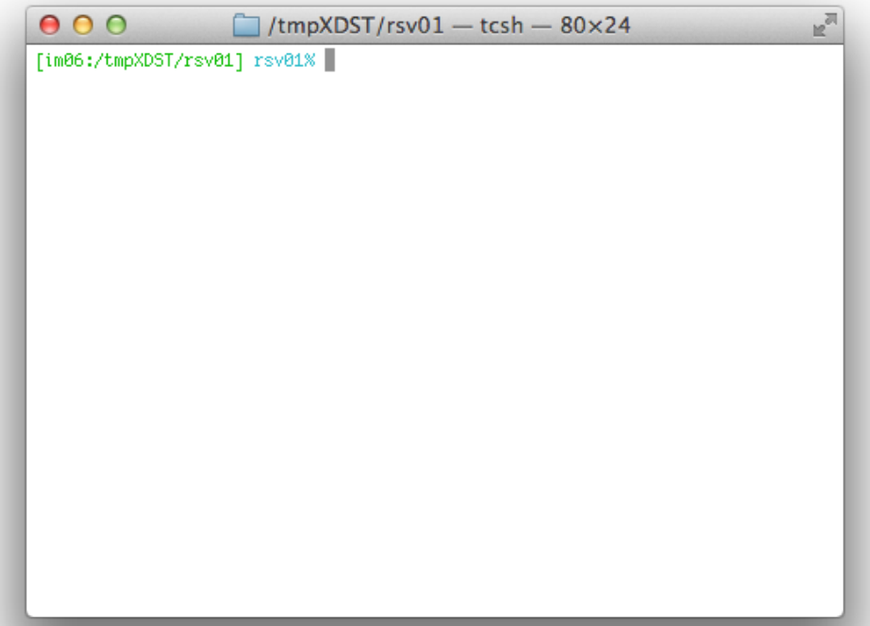
# Computer exercises - Terminal

- Local computer

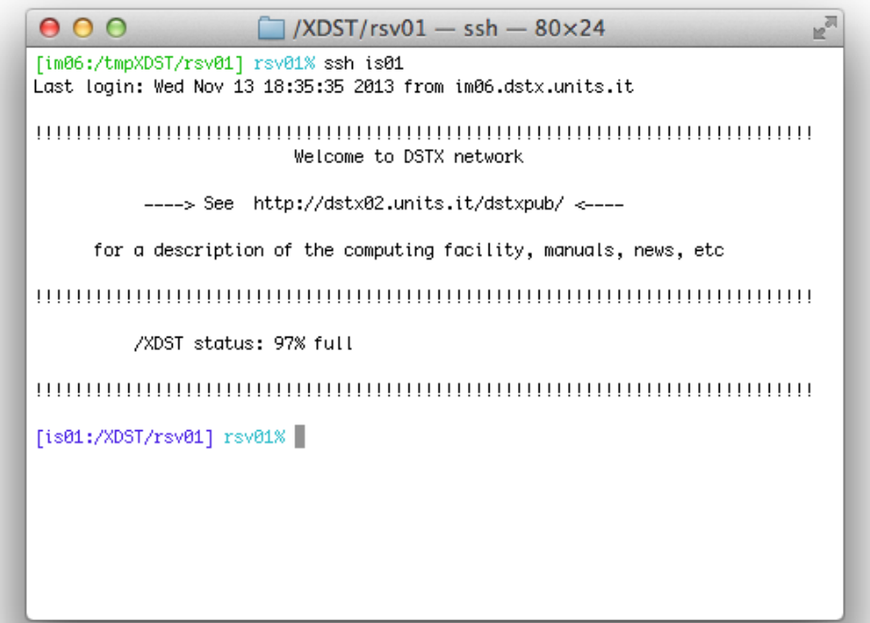


# Computer exercises - Terminal

- Local computer

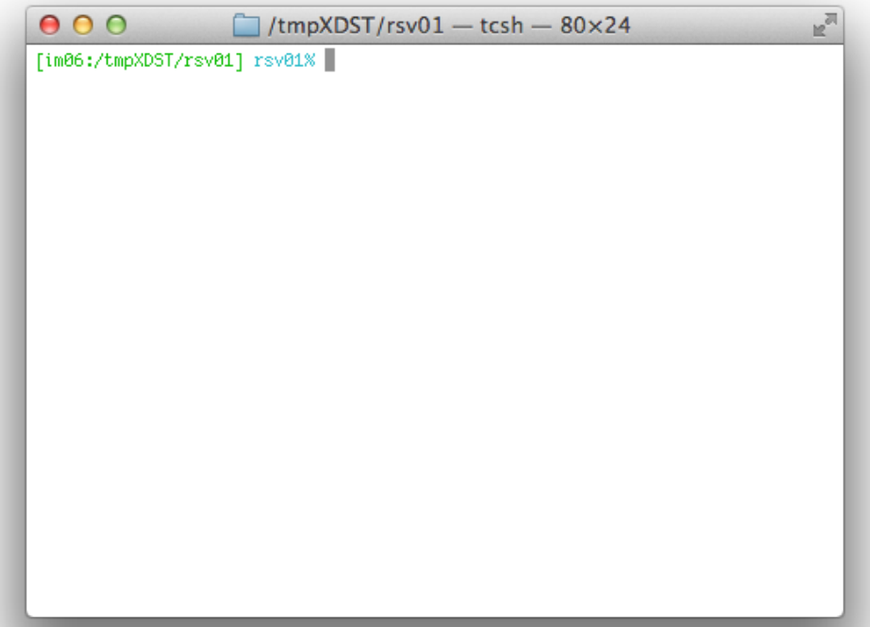



- Server (is01)

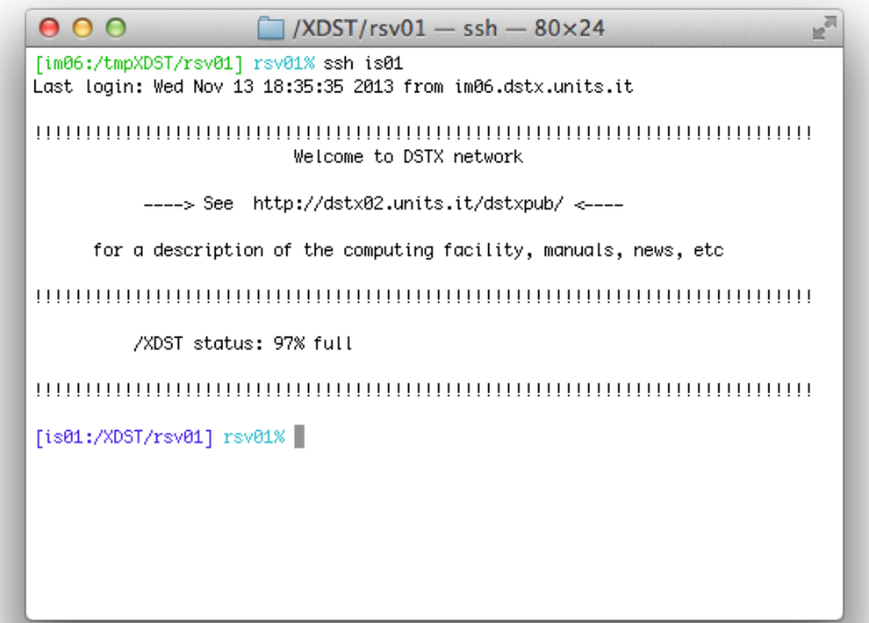


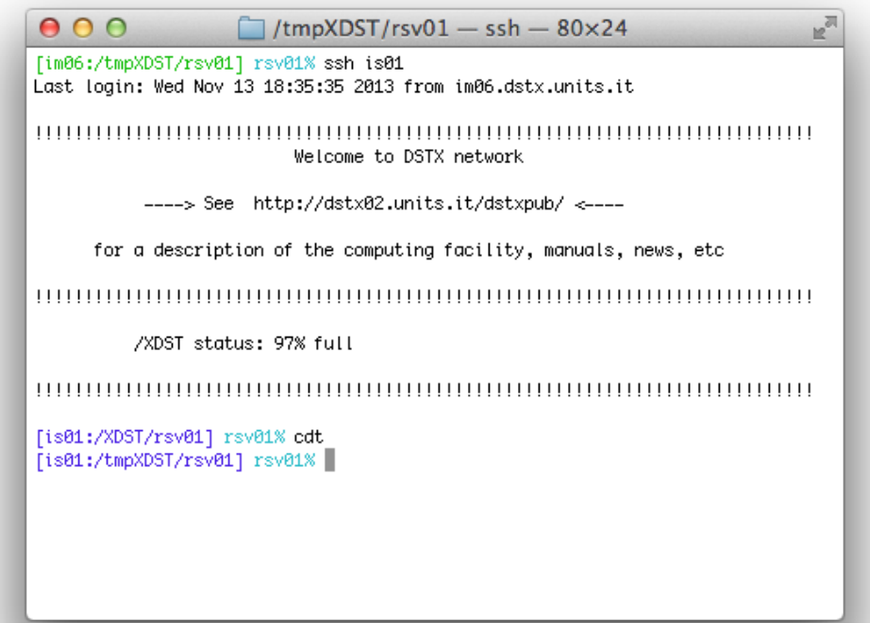
# Computer exercises - Terminal

- Local computer



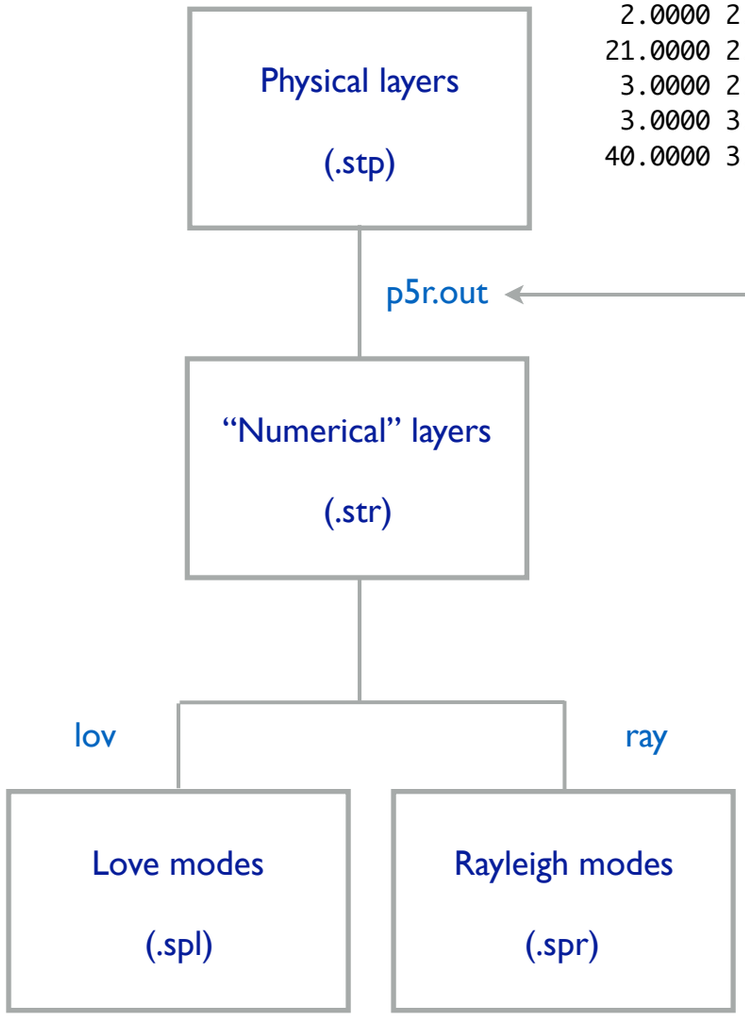

- Server (is01)



# Computer exercises - Modes computation

```
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  3.300000   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
```




```
Parameters file for program p5r
0                               reference structure (0 = none)
10.                             max frequency (10 Hz or 1 Hz or 0.1 Hz)
4.50                            min velocity for halfspace (1Hz=6.42,10Hz=4.50)
0.                              max depth (0=use vel; x=km,if in channel stay above)
1                               split more at physical interfaces (0=no, 1=YES)
1                               add num gradient to num layers (0=no, 1=YES)
1                               take care of low-velocity channels (0=no, 1=YES)
2.0                             largest Vs to split using wavelength (sugg. 2.0)
1.0                             wavelength correction factor (suggested 1.0)
0                               max depth for plotting (0=all)
svalp.stp                       physical layers first structure
```

# Once upon a time...

- 1985: it all started...
  - Synthetic seismograms: the Rayleigh waves modal summation (Panza, 1985)

$$u_x^R(x,z,\omega) = \sum_{m=1}^{\infty} \frac{e^{-i3\pi/4}}{\sqrt{8\pi\omega}} \frac{e^{-ik_m x}}{\sqrt{x}} \frac{\left(\chi_m^R(h_s,\omega)\right)}{\sqrt{c_m v_m I_m}} \frac{\left(F_x(z,\omega)\right)}{\sqrt{v_m I_m}}$$

$$u_z^R(x,z,\omega) = \sum_{m=1}^{\infty} \frac{e^{-i\pi/4}}{\sqrt{8\pi\omega}} \frac{e^{-ik_m x}}{\sqrt{x}} \frac{\left(\chi_m^R(h_s,\omega)\right)}{\sqrt{c_m v_m I_m}} \frac{\left(F_z(z,\omega)\right)}{\sqrt{v_m I_m}}$$

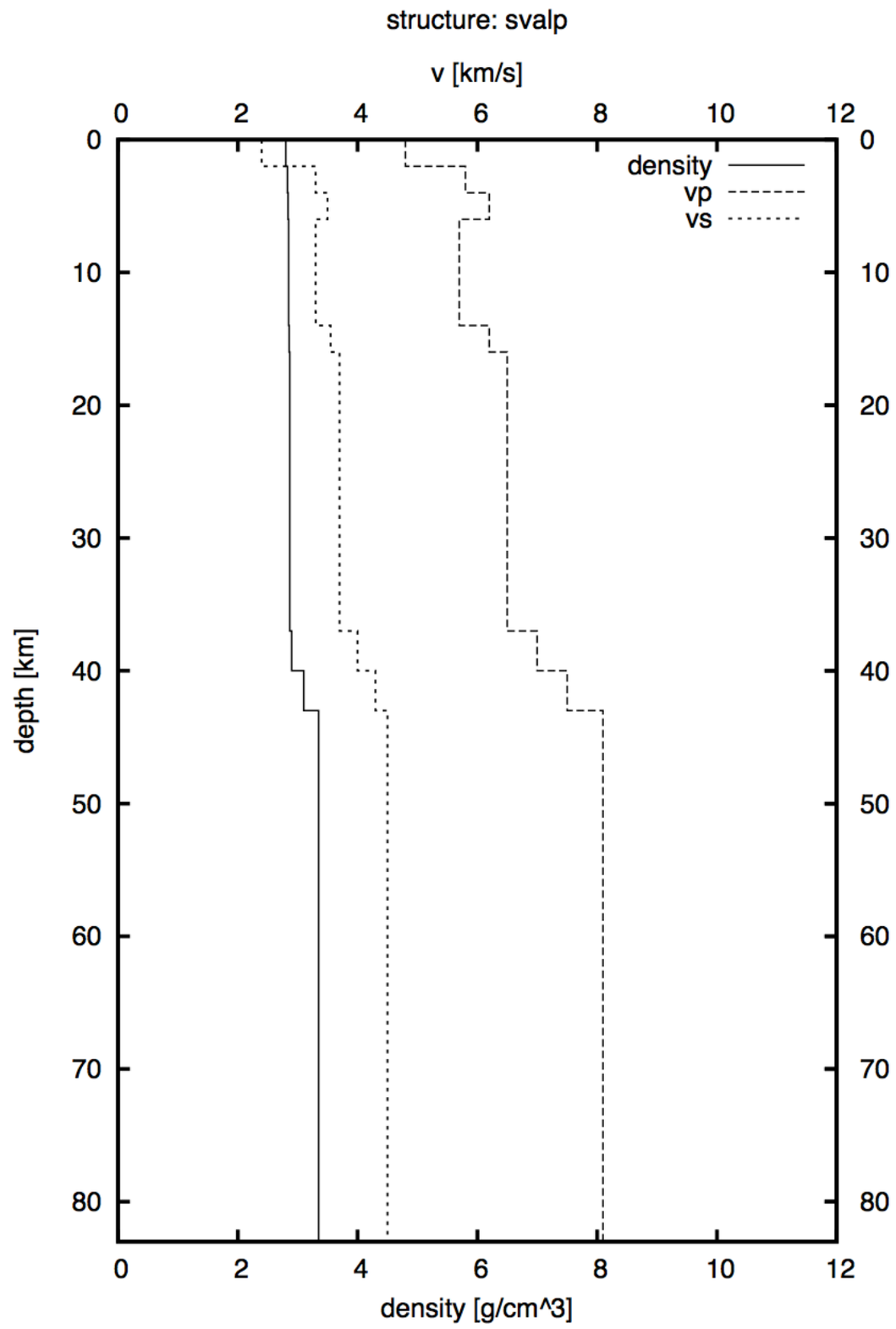
source structure receiver

# Once upon a time...

- 1985: it all started...
  - Structure definition 😕

# Once upon a time...

- 1985: it all started...
  - Structure definition 🙂



# Once upon a time...

- 1985: it all started...
  - Structure definition 😬

INPUT FOR RAYLEIGH WAVES MODES - PART 1

| | | |
|---|---|---|
| NAME OF STRUCTURE | SVALP.S | NAMESTR |
| MAXIMUM FREQUENCY | 0.10000E+02 | XMAXFR |
| TOTAL NUMBER OF SOLID LAYERS | 89 | N |
| NUMBER OF OCEANIC LAYERS | 0 | MSMAX |
| MAX. NUMBER OF MODES TO BE COMPUTED | 0 | MODETR |
| MANTLE CHANNEL (XMAXFR=10===>LITHOSPHERIC) PARAMETERS | | |
| PRESENCE OF TYPE 2 CHANNEL IN LID | 0 | ICHLID |
| S-WAVE VELOCITY OF TYPE2 CHANNEL ( - 12% ) | 0.00000E+00 | UMIN |
| CORRESPONDING S-WAVE PHASE ATTENUATION | 0.00000E+00 | UMINAT |
| S-WAVE VELOCITY AT BOTTOM OF TYPE2 CHANNEL | 0.00000E+00 | UMAX |
| CORRESPONDING S-WAVE PHASE ATTENUATION | 0.00000E+00 | UMAXAT |
| HIGHEST INTERFACE OF TYPE 1 CHANNEL | 27 | ITOPMC |
| LOWEST INTERFACE OF TYPE 1 CHANNEL | 44 | ICH1 |
| MIN. S-WAVE VELOCITY IN TYPE 1 CHANNEL | 0.33001E+01 | BCH |
| CORRESPONDING S-WAVE PHASE ATTENUATION | 0.75755E-03 | BC99AT |
| MAX.S-WAVE VELOC.(AVER.ABOV.TYPE1 CHANNEL) | 0.28501E+01 | BLCRST |
| | | BCCRAT |

SOLID PART

| I ** NA | THICKNESS THKNES(I) | DENSITY RHO(I) | P-WAVE VELOCITY A1(I) | P-WAVE ATTENUATION A2(I) | S-WAVE VELOCITY B1(I) | S-WAVE ATTENUATION B2(I) |
|---|---|---|---|---|---|---|
| MA | 0.20000E+00 | 0.28000E+01 | 0.48000E+01 | 0.26042E-03 | 0.24000E+01 | 0.10417E-02 |
| TO | 0.20000E+00 | 0.28000E+01 | 0.48000E+01 | 0.26042E-03 | 0.24000E+01 | 0.10417E-02 |
| NU | 0.20000E+00 | 0.28000E+01 | 0.48000E+01 | 0.26042E-03 | 0.24000E+01 | 0.10417E-02 |
| MA | 0.20000E+00 | 0.28000E+01 | 0.48000E+01 | 0.26042E-03 | 0.24000E+01 | 0.10417E-02 |
| M | 0.20000E+00 | 0.28000E+01 | 0.48000E+01 | 0.26042E-03 | 0.24001E+01 | 0.10417E-02 |
| -- | 0.20000E+00 | 0.28000E+01 | 0.48000E+01 | 0.26042E-03 | 0.24001E+01 | 0.10417E-02 |
| PR | 0.20000E+00 | 0.28000E+01 | 0.48000E+01 | 0.26042E-03 | 0.24001E+01 | 0.10417E-02 |
| S- | 0.20000E+00 | 0.28000E+01 | 0.48000E+01 | 0.26042E-03 | 0.24001E+01 | 0.10417E-02 |
| CO | 0.18000E+00 | 0.28000E+01 | 0.48000E+01 | 0.26042E-03 | 0.24001E+01 | 0.10417E-02 |
| S- | 0.20000E-01 | 0.28000E+01 | 0.48000E+01 | 0.26042E-03 | 0.24002E+01 | 0.10417E-02 |
| CO | 0.25000E-01 | 0.28300E+01 | 0.58000E+01 | 0.21552E-03 | 0.33000E+01 | 0.75758E-03 |
| HI | 0.22500E+00 | 0.28300E+01 | 0.58000E+01 | 0.21552E-03 | 0.33000E+01 | 0.75758E-03 |
| LO | 0.25000E+00 | 0.28300E+01 | 0.58000E+01 | 0.21552E-03 | 0.33000E+01 | 0.75758E-03 |
| MI | 0.25000E+00 | 0.28300E+01 | 0.58000E+01 | 0.21552E-03 | 0.33000E+01 | 0.75758E-03 |
| CO | 0.25000E+00 | 0.28300E+01 | 0.58000E+01 | 0.21552E-03 | 0.33001E+01 | 0.75758E-03 |
| MA | 0.25000E+00 | 0.28300E+01 | 0.58000E+01 | 0.21552E-03 | 0.33001E+01 | 0.75758E-03 |
| MA | 0.25000E+00 | 0.28300E+01 | 0.58000E+01 | 0.21552E-03 | 0.33001E+01 | 0.75758E-03 |
| | 0.22500E+00 | 0.28300E+01 | 0.58000E+01 | 0.21552E-03 | 0.33001E+01 | 0.75758E-03 |
| | 0.25000E-01 | 0.28300E+01 | 0.58000E+01 | 0.21552E-03 | 0.33001E+01 | 0.75758E-03 |
| | 0.50000E-01 | 0.28400E+01 | 0.62000E+01 | 0.20161E-03 | 0.35000E+01 | 0.71429E-03 |
| | 0.45000E+00 | 0.28400E+01 | 0.62000E+01 | 0.20161E-03 | 0.35000E+01 | 0.71429E-03 |
| | 0.50000E+00 | 0.28400E+01 | 0.62000E+01 | 0.20161E-03 | 0.35000E+01 | 0.71429E-03 |
| | 0.50000E+00 | 0.28400E+01 | 0.62000E+01 | 0.20161E-03 | 0.35000E+01 | 0.71429E-03 |

| | S-WAVE ATTENUATION B2(I) |
|---|---|
| 1 | 0.10417E-02 |
| 1 | 0.10417E-02 |
| 1 | 0.10417E-02 |
| 1 | 0.10417E-02 |
| 1 | 0.10417E-02 |
| 1 | 0.10417E-02 |
| 1 | 0.10417E-02 |
| 1 | 0.10417E-02 |
| 01E+01 | 0.10417E-02 |
| 01E+01 | 0.10417E-02 |
| 02E+01 | 0.10417E-02 |
| 00E+01 | 0.75758E-03 |
| 00E+01 | 0.75758E-03 |
| 00E+01 | 0.75758E-03 |
| 00E+01 | 0.75758E-03 |
| 00E+01 | 0.75758E-03 |

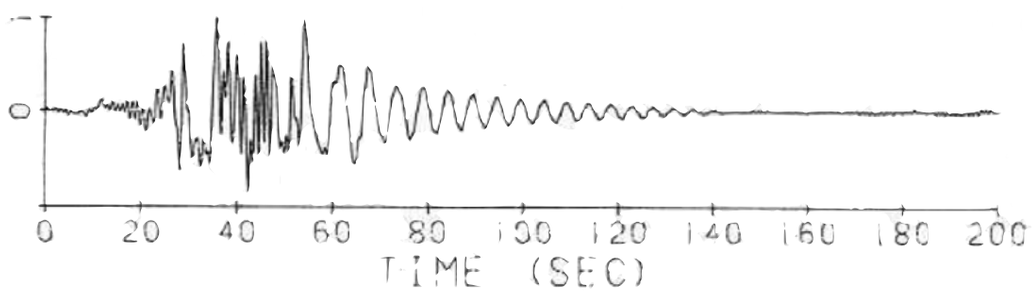
# Once upon a time...

- 1985: it all started...
  - Job submission on the Mainframe Computer of the Trieste University:
    - 😉 Submit in the evening...
    - 😐 Cross fingers...
    - 😀 Get the results in the morning...
    - 😬 Maybe...
    - 😆 Do it again...

```
I N P U T   F O R   R A Y L E I G H   W A V E S   M O D E S  -  P A R T 1
*************************************************************************
NAME OF STRUCTURE                              :     SVALP.S          NAMESTR
MAXIMUM FREQUENCY                              :  0.10000E+02         XMAXFR
TOTAL NUMBER OF SOLID LAYERS                   :       89             N
NUMBER OF OCEANIC LAYERS                       :        0             MSMAX
MAX. NUMBER OF MODES TO BE COMPUTED            :        0             MODETR
M A N T L E   C H A N N E L   (XMAXFR=10===>LITHOSPHERIC) PARAMETERS
-------------------------------------------------------------------------
PRESENCE OF TYPE 2 CHANNEL IN LID              :        0             ICHLID
S-WAVE VELOCITY OF TYPE2 CHANNEL ( - 12% )     :  0.00000E+00         UMIN
CORRESPONDING S-WAVE PHASE ATTENUATION         :  0.00000E+00         UMINAT
S-WAVE VELOCITY AT BOTTOM OF TYPE2 CHANNEL     :  0.00000E+00         UMAX
CORRESPONDING S-WAVE PHASE ATTENUATION         :  0.00000E+00         UMAXAT
HIGHEST INTERFACE OF TYPE 1 CHANNEL            :       27             ITOPMC
LOWEST INTERFACE OF TYPE 1 CHANNEL             :       44             ICH1
MIN. S-WAVE VELOCITY IN TYPE 1 CHANNEL         :  0.33001E+01         BCH
CORRESPONDING S-WAVE PHASE ATTENUATION         :  0.75755E-03         BC99AT
MAX.S-WAVE VELOC.(AVER.ABOV.TYPE1 CHANNEL)     :  0.28501E+01         BLCRST
MAX.S-WAVE PHASE ATT.(ABOVE TYPE1 CHANNEL)     :  0.10417E-02         BCCRAT
```

# Once upon a time...

- 1985: it all started...
  - Synthetic seismograms: the Rayleigh waves modal summation (Panza, 1985)




| | |
|---|---|
| DISPLACEMENT | SIMPSO1 |
| STRUCTURE | IMP1 |
| COMPONENT | RADIAL |
| SUMMED MODES | 214. |
| SCALE AMPLITUDE (CM) | $7.8693 \cdot 10^{-25}$ |
| **SOURCE** | |
| DISTANCE (KM) | 100.00 |
| DEPTH (KM) | 8.00 |
| STRIKE (DEG) | 225. |
| DIP (DEG) | 90. |
| RAKE (DEG) | 0. |
| DURATION (S) | 0.00 |
| FILTER | NO |
| INSTRUMENT | NO |

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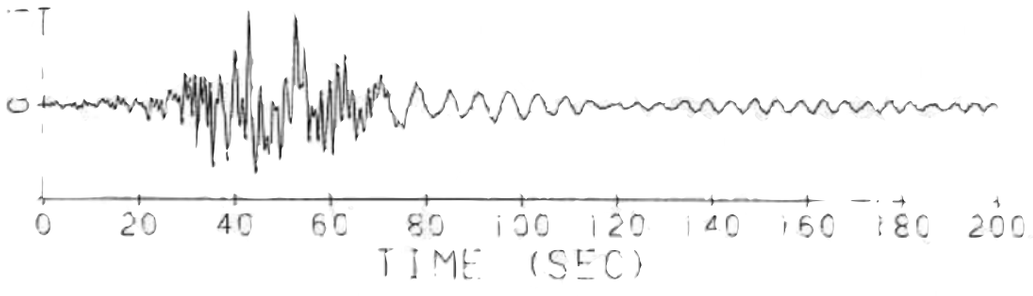


| | |
|---|---|
| DISPLACEMENT | SIMPSV2 |
| STRUCTURE | IMP1 |
| COMPONENT | VERTICAL |
| SUMMED MODES | 214. |
| SCALE AMPLITUDE (CM) | $3.9362 \cdot 10^{-25}$ |
| **SOURCE** | |
| DISTANCE (KM) | 150.00 |
| DEPTH (KM) | 8.00 |
| STRIKE (DEG) | 225 |
| DIP (DEG) | 90. |
| RAKE (DEG) | 0 |
| DURATION (S) | 0.00 |
| FILTER | NO |
| INSTRUMENT | NO |

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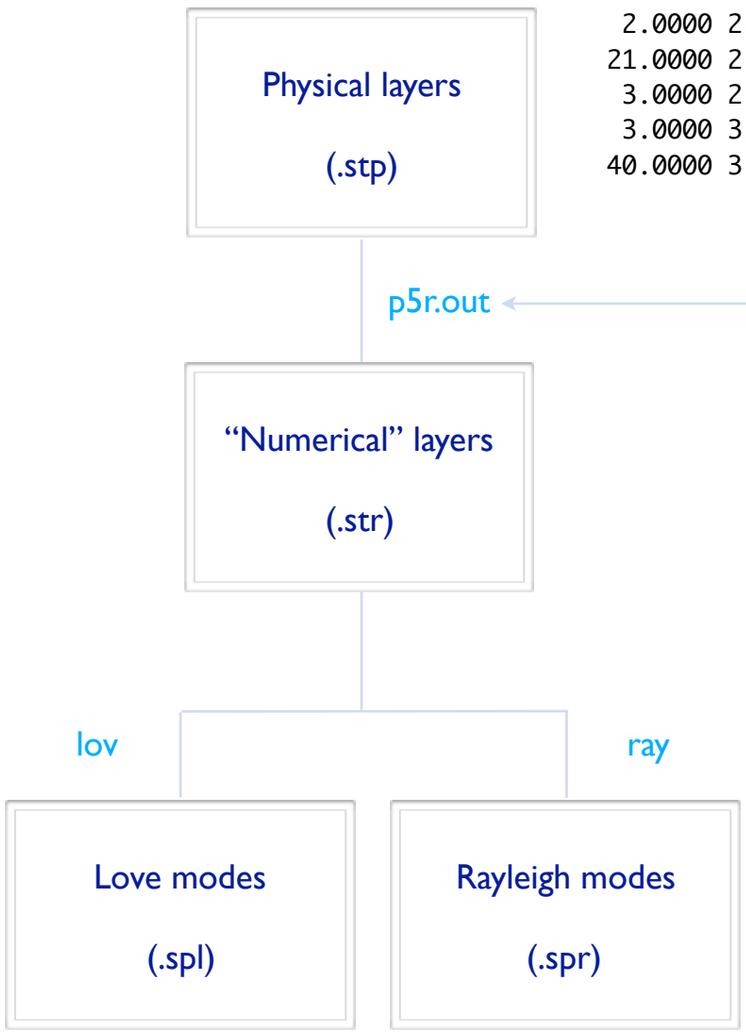
# Now...

- Mode computation: 1/2 day ⇢ seconds
- Single event scenario: hour ⇢ seconds
- Seismic zonation at national scale: days ⇢ hours
- Seismic zonation at local scale: week ⇢ hours

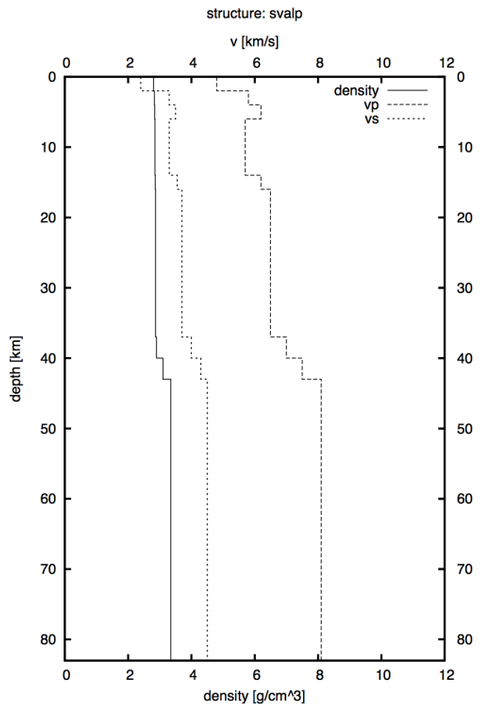
# Computer exercises - Modes computation

```
thk(km) rho   Vp(km/s)  Vs(km/s)    Qp       Qs     depth(km) layer
 2.0000 2.80  4.800000  2.400000   399.99   199.99    2.00000   1
 2.0000 2.83  5.800000  3.300000   399.99   200.00    4.00000   2
 2.0000 2.84  6.200000  3.500000   400.01   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   400.01   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   399.99   200.00   43.00000   8
40.0000 3.35  8.100000  4.500000   400.00   200.00   83.00000   9
```




```
Parameters file for program p5r
0                                   reference structure (0 = none)
10.                                 max frequency (10 Hz or 1 Hz or 0.1 Hz)
4.50                                min velocity for halfspace (1Hz=6.42,10Hz=4.50)
0.                                  max depth (0=use vel; x=km,if in channel stay above)
1                                   split more at physical interfaces (0=no, 1=YES)
1                                   add num gradient to num layers (0=no, 1=YES)
1                                   take care of low-velocity channels (0=no, 1=YES)
2.0                                 largest Vs to split using wavelength (sugg. 2.0)
1.0                                 wavelength correction factor (suggested 1.0)
0                                   max depth for plotting (0=all)
svalp.stp                           physical layers first structure
```

# Computer exercises - Modes computation




"Numerical" layers

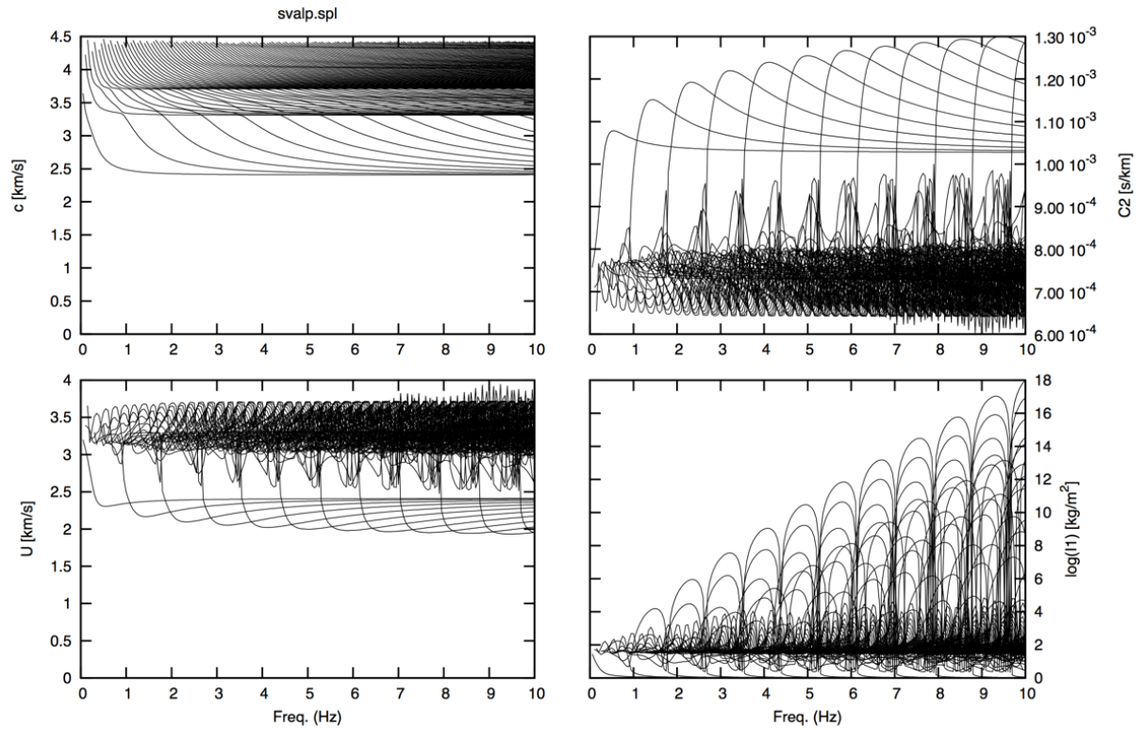
(.str)

lov

ray

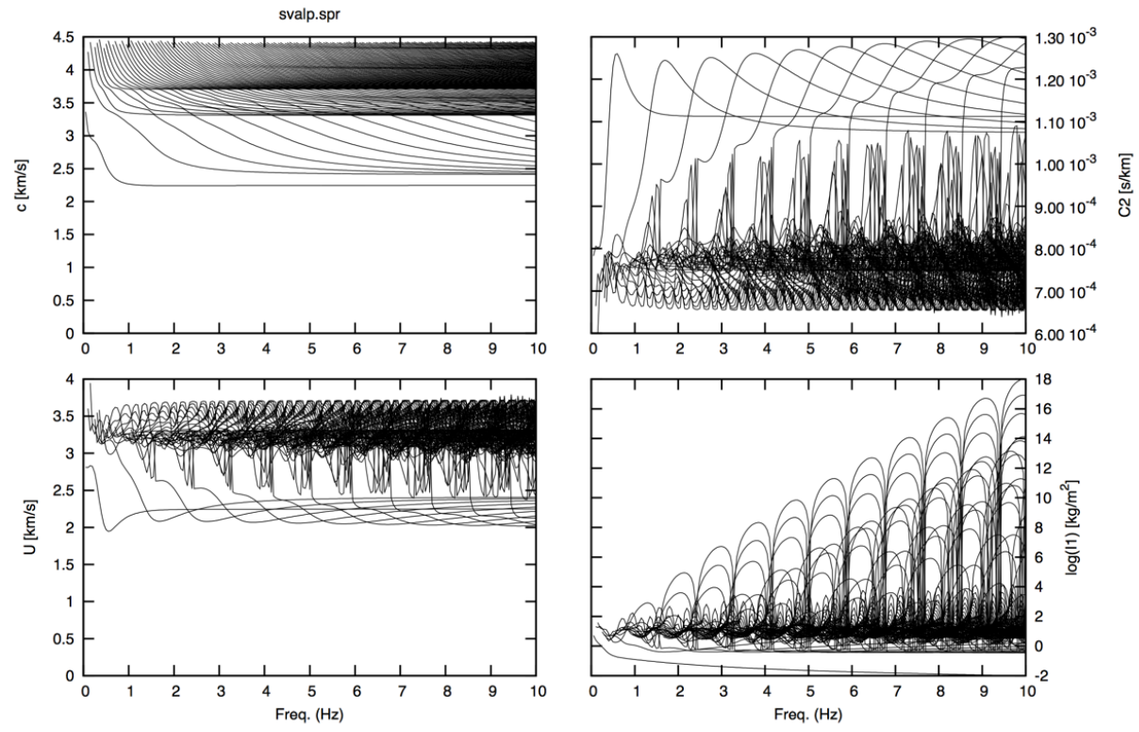
Love modes

(.spl)



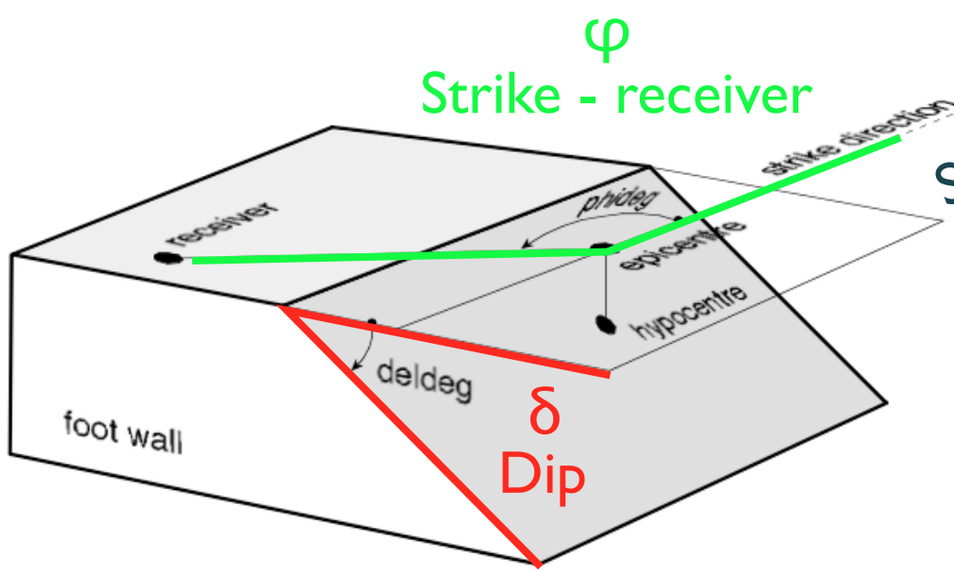

Rayleigh modes

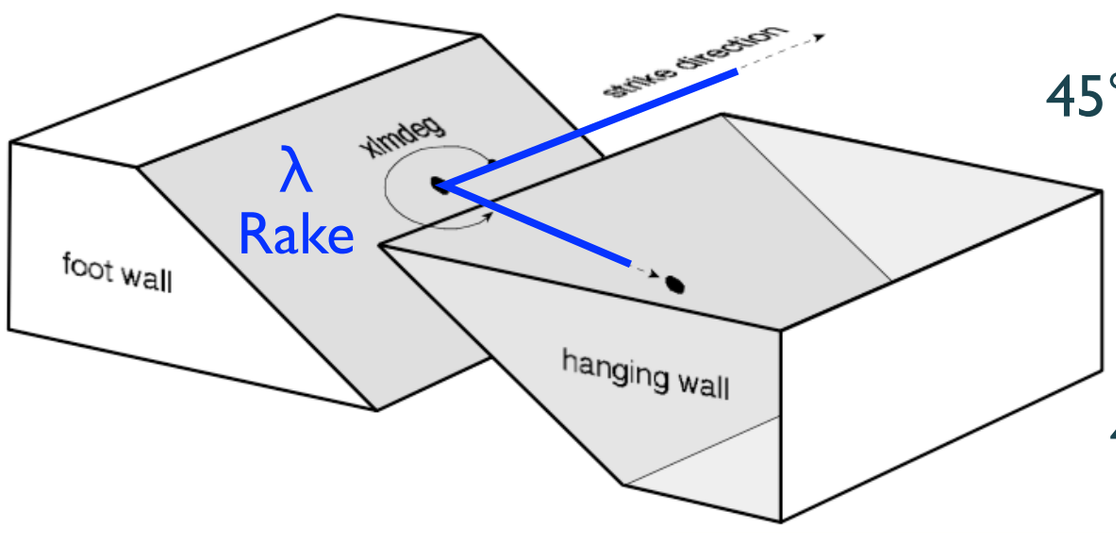
(.spr)



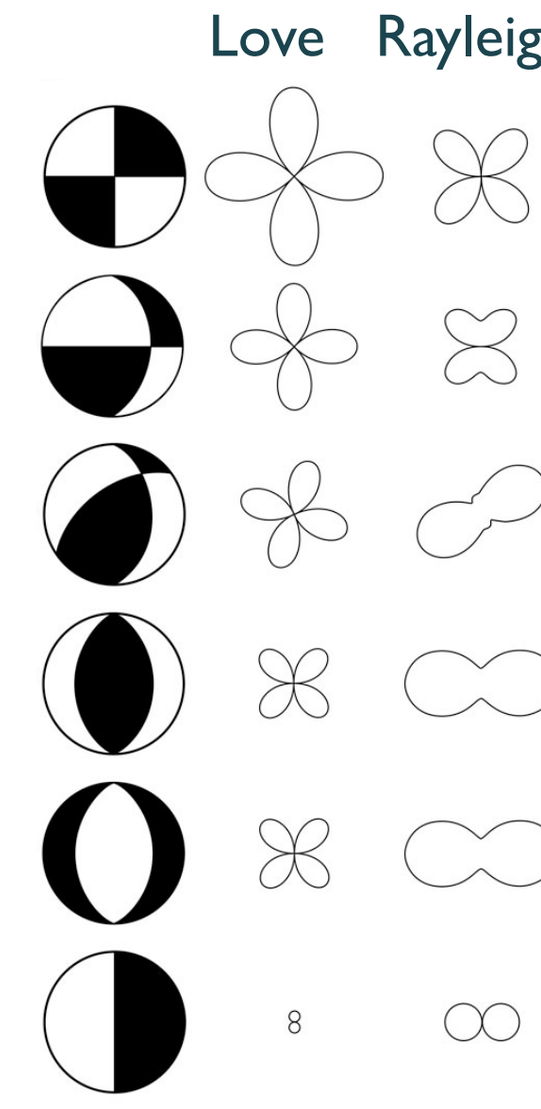
# Computer exercises - Source definition

## Source definition and examples of radiation pattern




$$\left(\chi_m^L(h_s,\omega)\right) \qquad \left(\chi_m^R(h_s,\omega)\right)$$



# Computer exercises - Source definition

- Expression of the source radiation pattern

$$\chi_L = i(d_{1L}\sin\varphi + d_{2L}\cos\varphi) + d_{3L}\sin 2\varphi + d_{4L}\cos 2\varphi$$
$$\chi_R = d_0 + i(d_{1R}\sin\varphi + d_{2R}\cos\varphi) + d_{3R}\sin 2\varphi + d_{4R}\cos 2\varphi$$

where

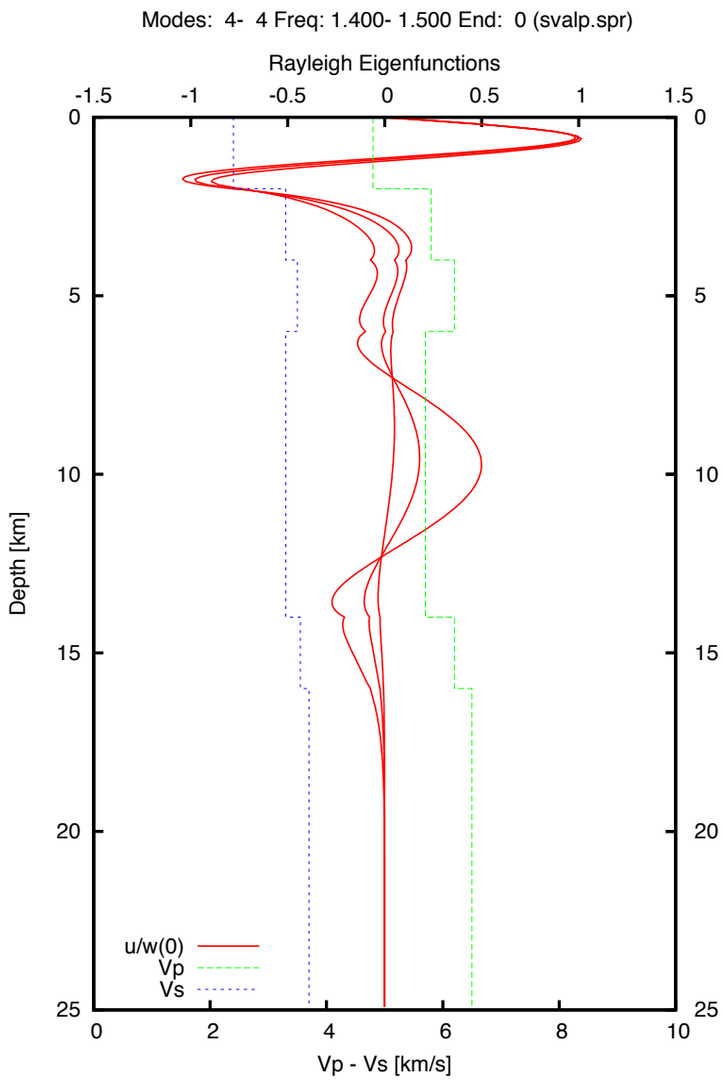
$$d_{1L} = G(h_s)\cos\lambda\sin\delta \qquad d_0 = \frac{1}{2}B(h_s)\sin\lambda\sin 2\delta$$
$$d_{2L} = -G(h_s)\sin\lambda\cos 2\delta \qquad d_{1R} = -C(h_s)\sin\lambda\cos 2\delta$$
$$d_{3L} = \frac{1}{2}V(h_s)\sin\lambda\sin 2\delta \qquad d_{2R} = -C(h_s)\cos\lambda\cos\delta$$
$$d_{4L} = V(h_s)\cos\lambda\sin\delta \qquad d_{3R} = A(h_s)\cos\lambda\sin\delta$$
$$d_{4R} = -\frac{1}{2}A(h_s)\sin\lambda\sin 2\delta$$

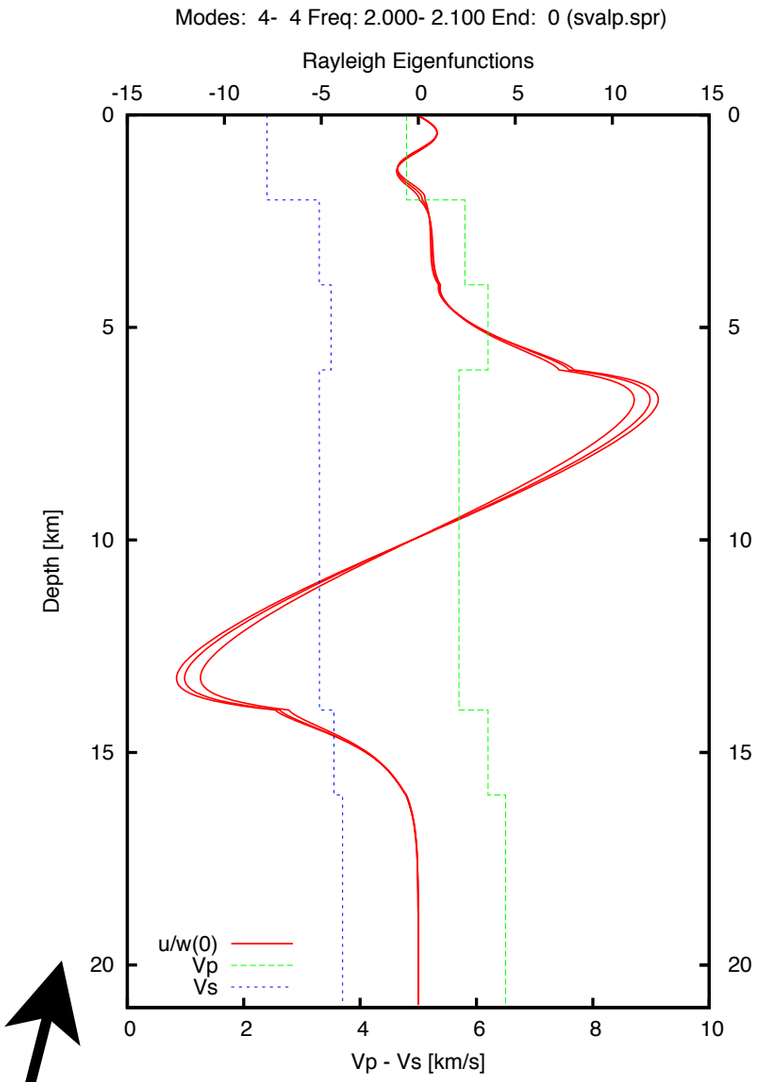
$$A(h_s) = -\frac{F_x^*(h_s)}{F_z(0)}$$
$$B(h_s) = -\left(3 - 4\frac{\beta^2(h_s)}{\alpha^2(h_s)}\right)\frac{F_x^*(h_s)}{F_z(0)} - \frac{2}{\rho(h_s)\,\alpha^2(h_s)}\frac{\sigma_{zz}^*(h_s)}{\dot{F}_z(0)/c}$$
$$C(h_s) = -\frac{1}{\mu(h_s)}\frac{\sigma_{zx}(h_s)}{\dot{F}_z(0)/c}$$
$$G(h_s) = -\frac{1}{\mu(h_s)}\frac{\sigma_{zy}^*(h_s)}{\dot{F}_y(0)/c}$$
$$V(h_s) = \frac{\dot{F}_y(h_s)}{\dot{F}_y(0)/c} = \frac{F_y(h_s)}{F_y(0)/c}$$

$$\left(\chi_m^L(h_s,\omega)\right) \qquad \left(\chi_m^R(h_s,\omega)\right)$$

# Computer exercises - Eigenfunctions

## Eigenfunctions



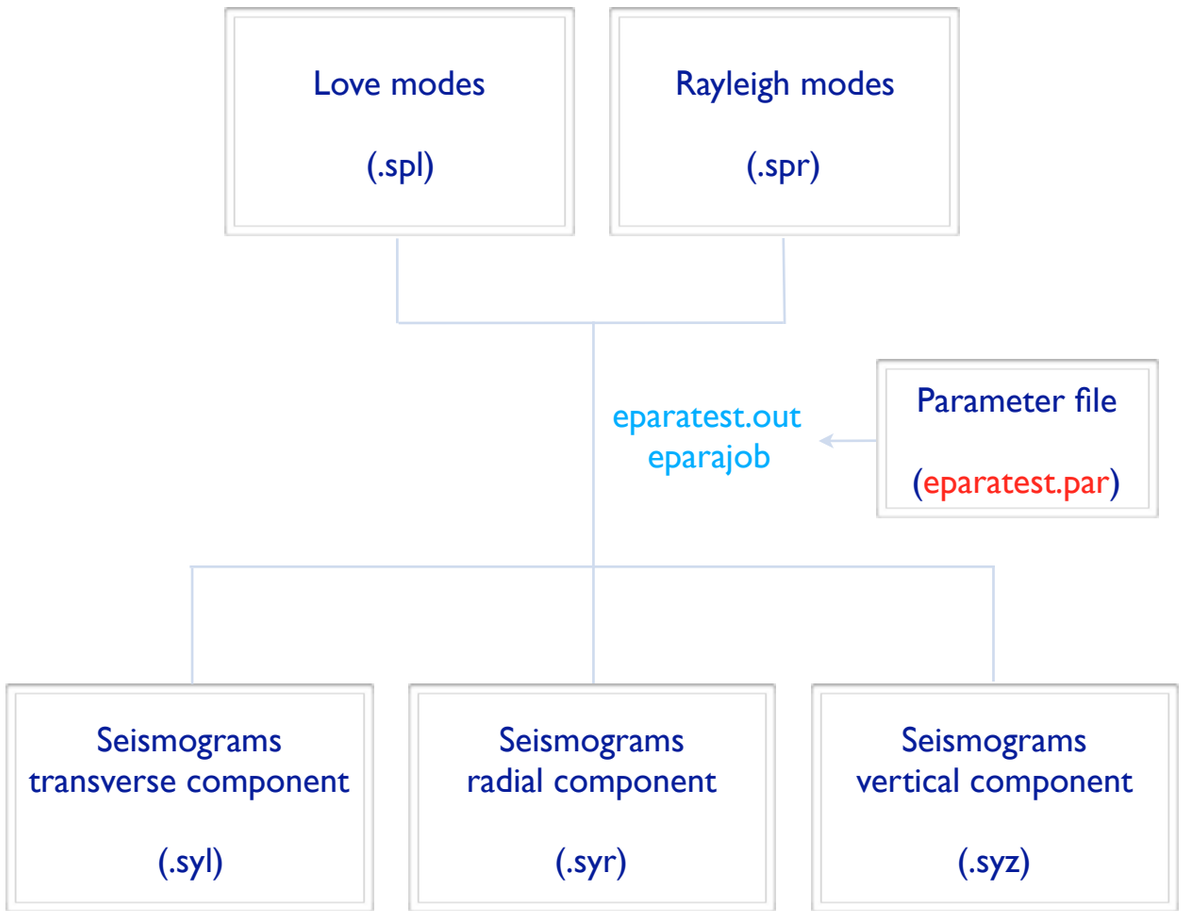

4 dispersed

not dispersed

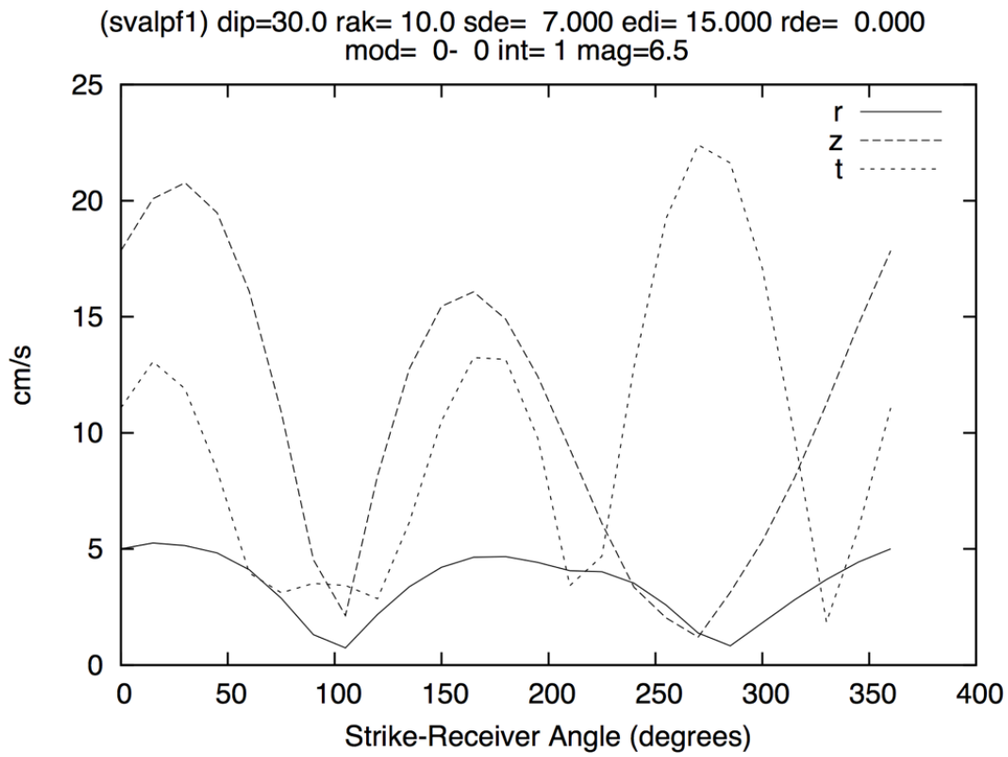
dispersed

# Computer exercises - Synthetic seismograms

## Parametric tests

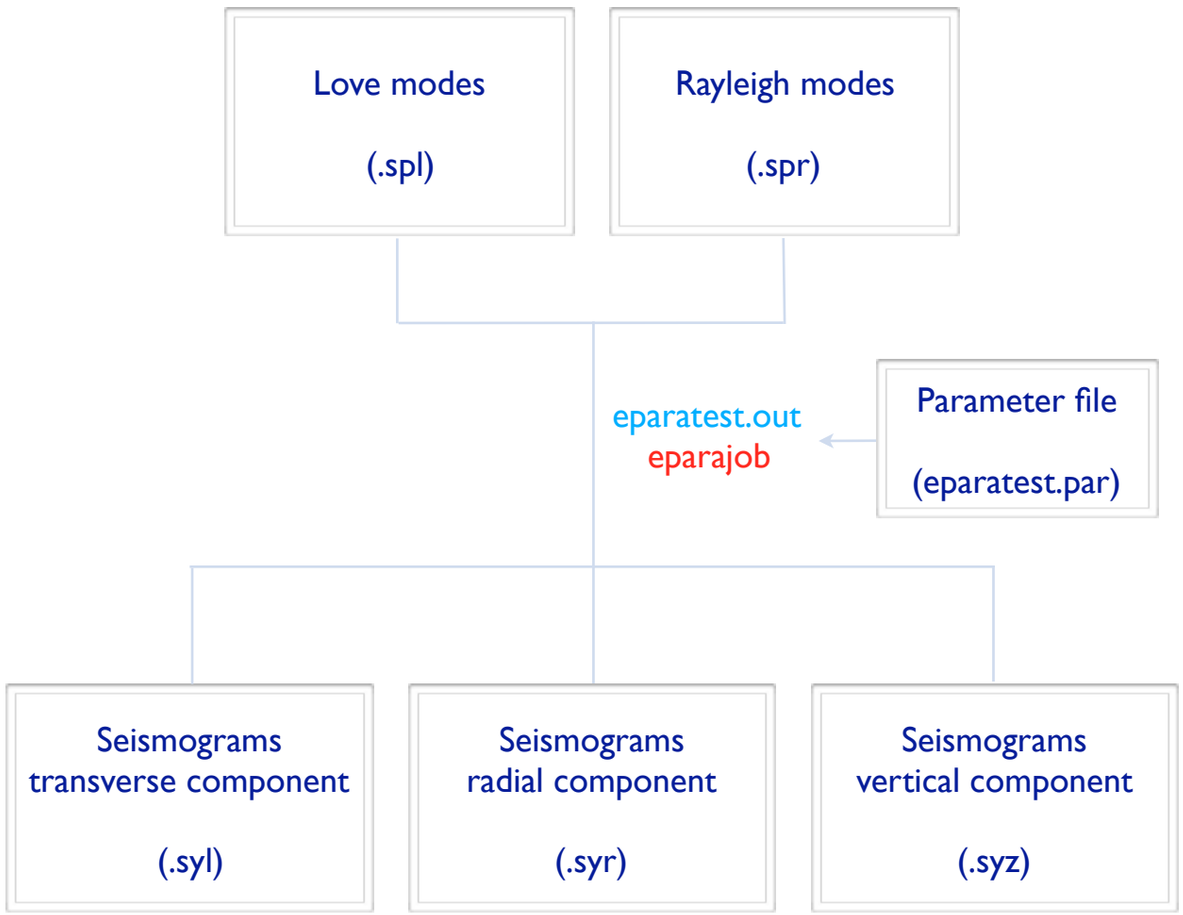



```
Parameter file for program eparatest
-------------------------------------------------------------------------------
svalp                 Test label (root for output filenames - 13 chars max)
0                     Ref. box for values not listed below (0=no, 13 chars max)
svalp.spl             Love spectrum file
svalp.spr             Rayleigh spectrum file
2                     Motion (1=displ, 2=vel, 3=acc)
50                    Time length for plot seismograms (s)
1  13.0 45.0 80       Source (1=point, 2=extended), lon, lat, strike (Nord)
SRE 1   0 360 15      Strike (loop 0=no,1=yes, start, stop, step) (Degrees)
DIP 0  30  90 10      Dip (loop 0=no,1=yes, start, stop, step) (Degrees)
RAK 0  10  40 10      Rake (loop 0=no,1=yes, start, stop, step) (Degrees)
SDE 0   7   9  1      Source Depth (loop 0=no/1=yes, start, stop, step) (km)
EDI 0  15 200 15      Epic. Distance (loop 0=no/1=yes, start, stop, step) (km)
RDE 0   0   3  1      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   1  30  1      Interpolation (0-9) (flag 0=no,1=yes, start, stop, step)
MAG 0 6.5 7.0 .1      Magnitude (flag 0=no,1=yes, start, stop, step)
```



# Computer exercises - Synthetic seismograms

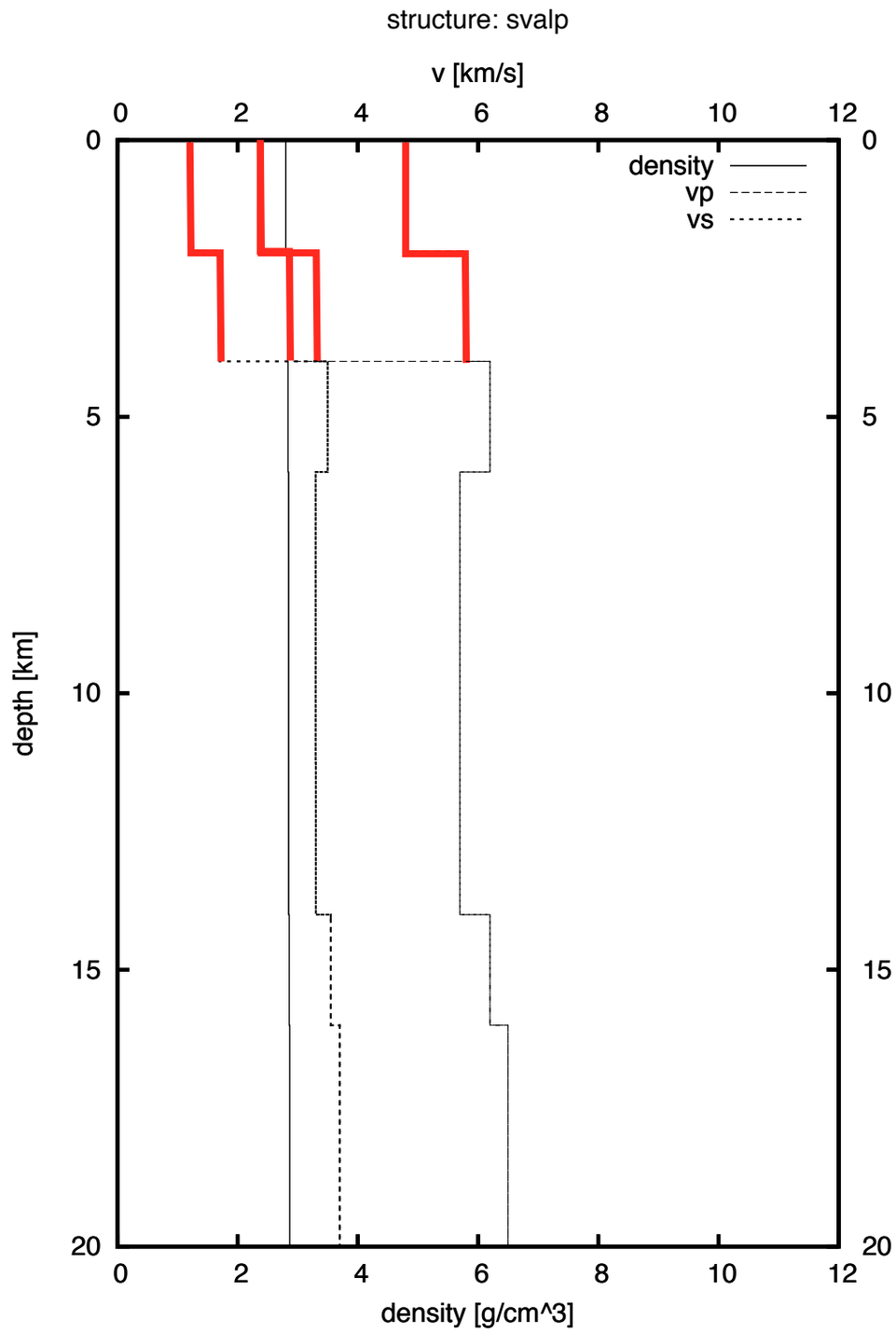
## Parametric tests




```
#!/bin/bash
set -e
echo $$ > eparajob.pid
date>svalpparajob.pri
echo "Start of parajob job">>svalpparajob.pri
cp syr.cntl.r syr.cntl
echo "Computing Radial Component..."
syr0048.out
date>>svalpparajob.pri
echo "Radial Computed">>svalpparajob.pri
cp syr.cntl.z syr.cntl
echo "Computing Vertical Component..."
syr0048.out
date>>svalpparajob.pri
echo "Vertical Computed">>svalpparajob.pri
cp syl.cntl.t syl.cntl
echo "Computing Transverse Component..."
syl0048.out
date>>svalpparajob.pri
echo "Transverse Computed">>svalpparajob.pri
date>>svalpparajob.pri
echo "Scaling seismograms..."
efft.out
echo "Computing Resultant, NS and EW Components..."
rot.out
date>>svalpparajob.pri
cat tmploop | awk '{ print $1,$2 }'  > tmploopsel
grep amaxa svalpf1.syr | awk '{ print $8 }'  > tmpr
grep amaxa svalpf1.syz | awk '{ print $8 }'  > tmpz
grep amaxa svalpf1.syl | awk '{ print $8 }'  > tmpl
grep amaxa svalpf1.res | awk '{ print $9 }'  > tmpres
grep amaxa svalpf1.sns | awk '{ print $8 }'  > tmpsns
grep amaxa svalpf1.sew | awk '{ print $8 }'  > tmpsew
echo '#num sre  PGV rad   PGV ver   PGV tra   PGV res   PGV sns   PGV sew   dip=30.0
rak= 10.0 sde=  7.000 edi= 15.000 rde=  0.000\n\ mod=  0-  0 int= 1 mag=6.5' >
svalp.sta
paste tmploopsel tmpr tmpz tmpl tmpres tmpsns tmpsew >> svalp.sta
minmax -C tmpr | awk '{ print $2 }' > tmpsort
minmax -C tmpz | awk '{ print $2 }' >> tmpsort
minmax -C tmpl | awk '{ print $2 }' >> tmpsort
minmax -C tmpres | awk '{ print $2 }' >> tmpsort
minmax -C tmpsns | awk '{ print $2 }' >> tmpsort
minmax -C tmpsew | awk '{ print $2 }' >> tmpsort
MAX=`(cat tmpsort | sort -rn | head -1 )`
rm -f tmploop tmploopsel tmpr tmpz tmpl tmpres tmpsns tmpsew tmpsort *.plot
gnuplot svalp.sre.gplot
echo " "
sisplots.pl
echo "*** To plot the seismograms: gs svalp.sre.sis.*.ps"
echo "*** To plot the peak values: gs svalp.sre.ps"
echo " "
```

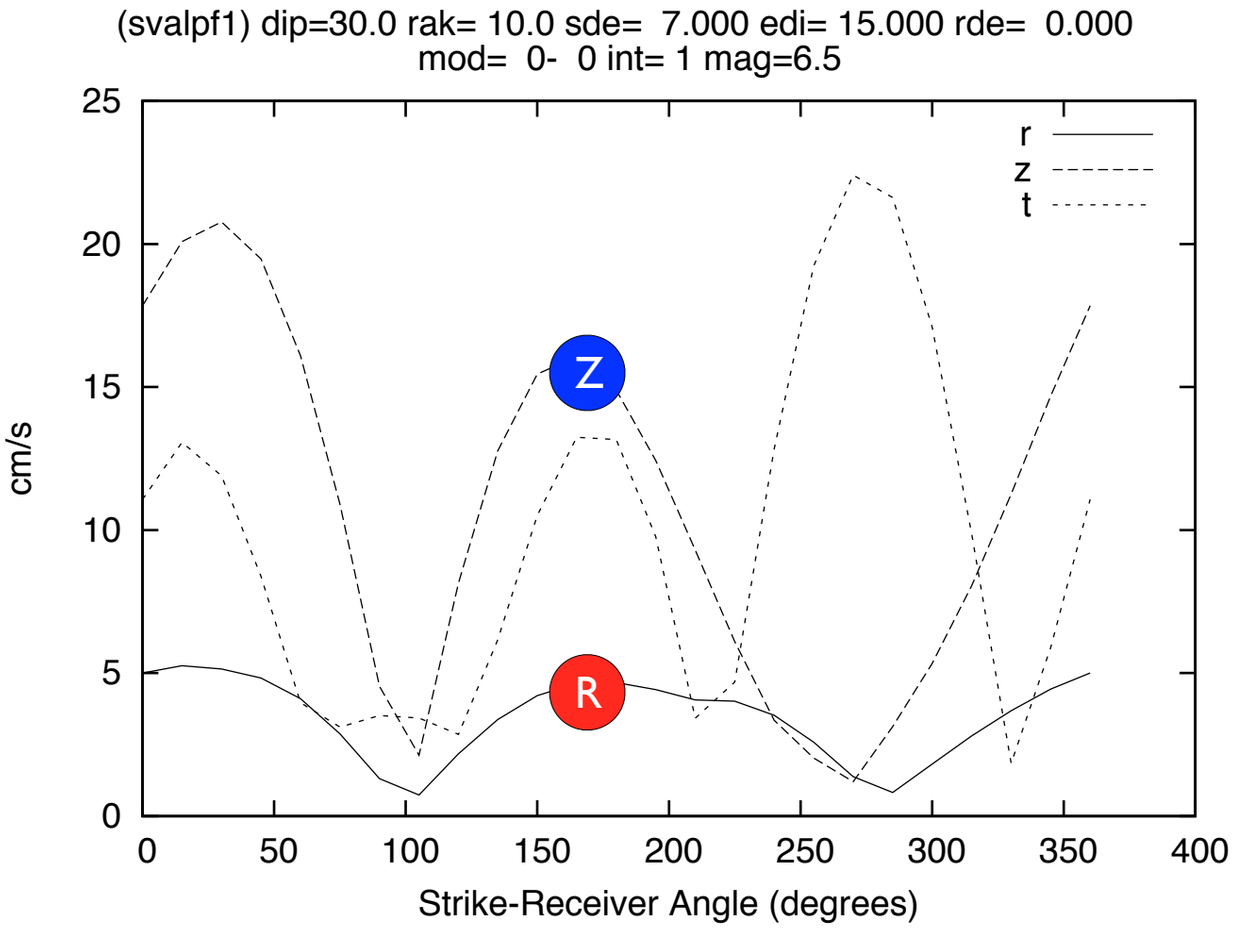
# Computer exercises - Synthetic seismograms

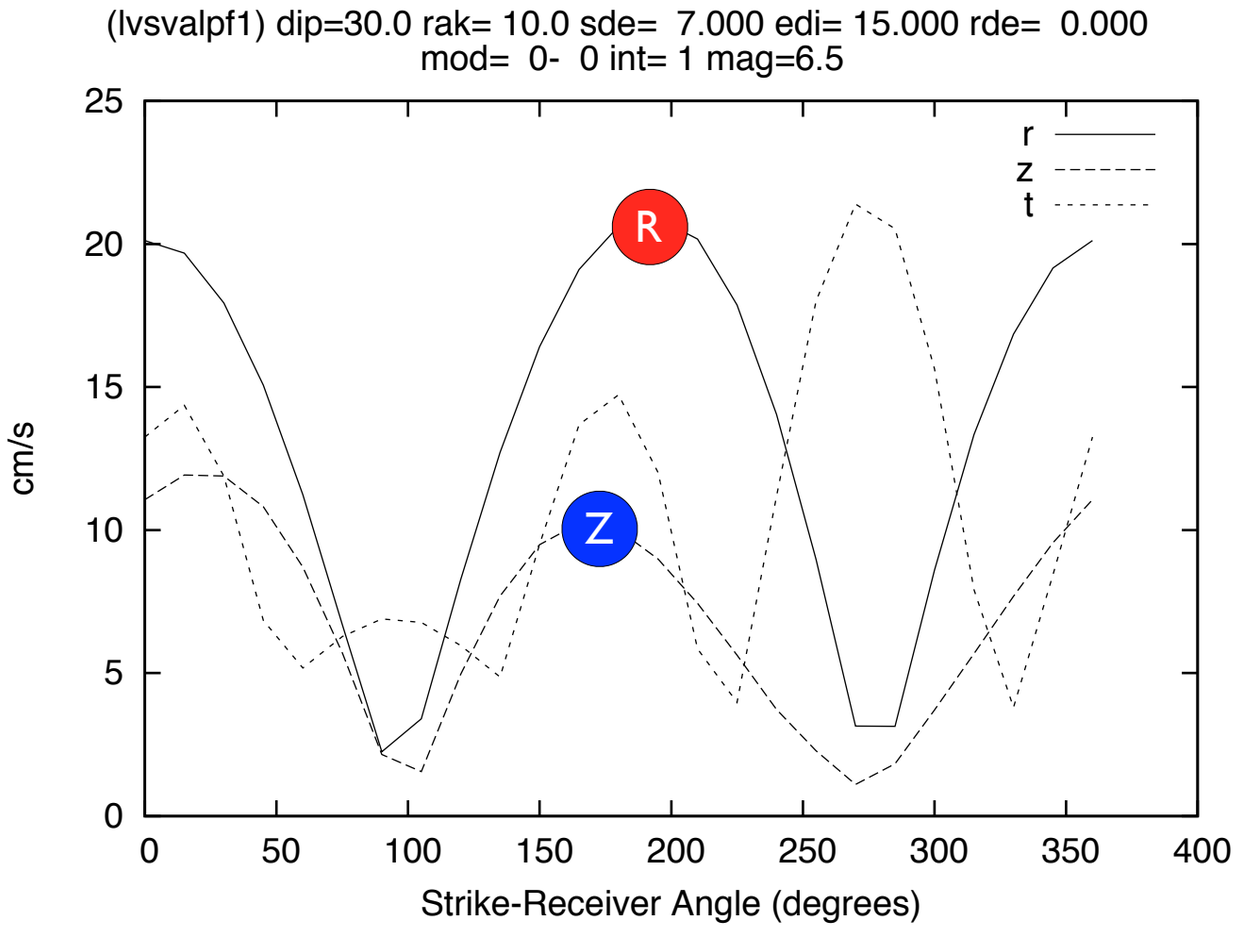
- Parametric tests

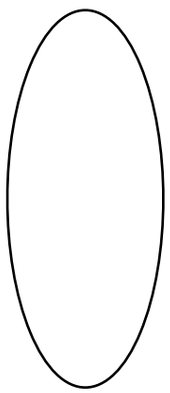


# Computer exercises - Synthetic seismograms

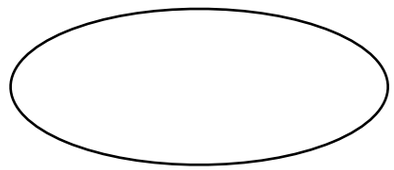
## Parametric tests



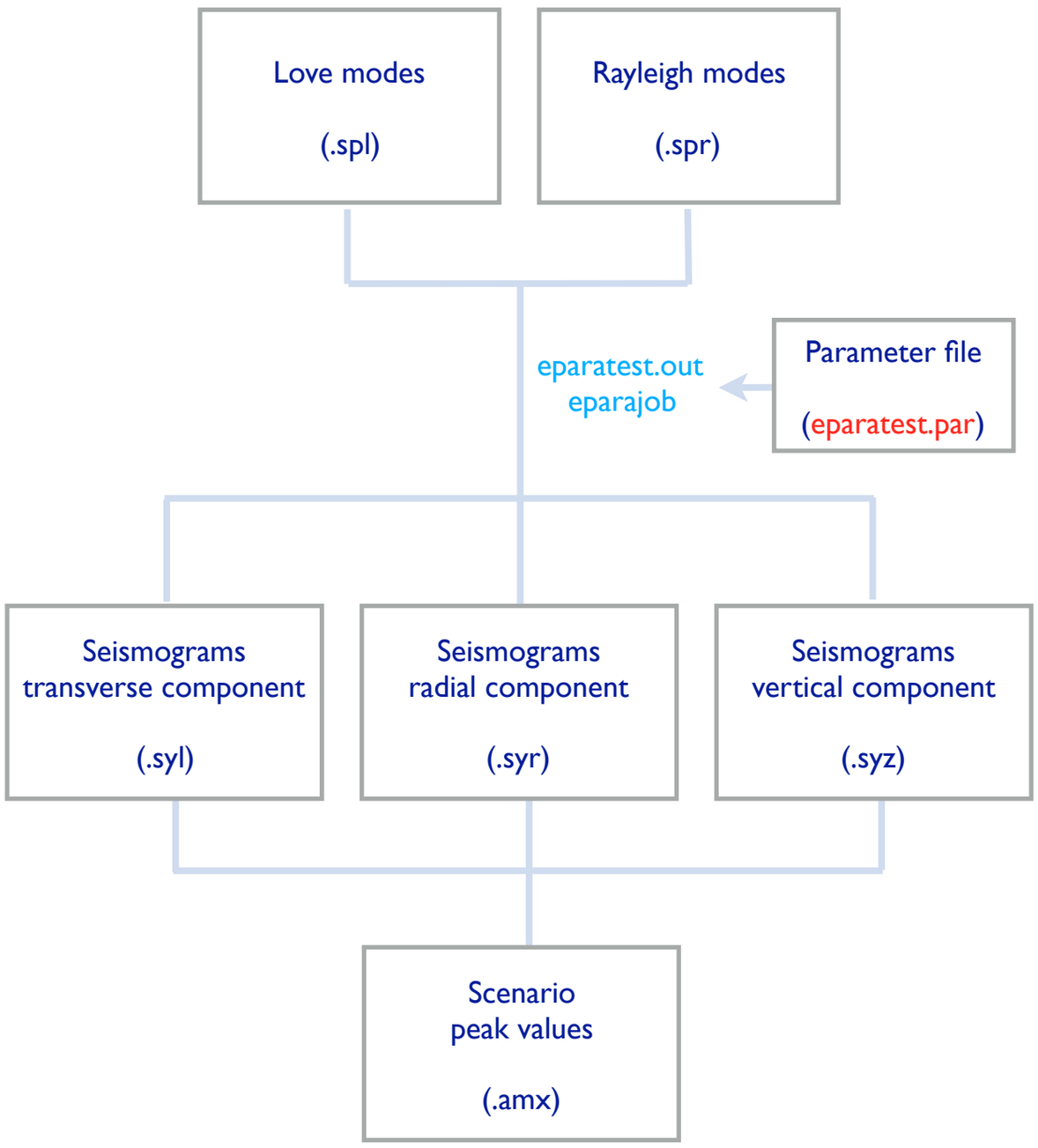



## Ellipticity of Rayleigh waves particle motion

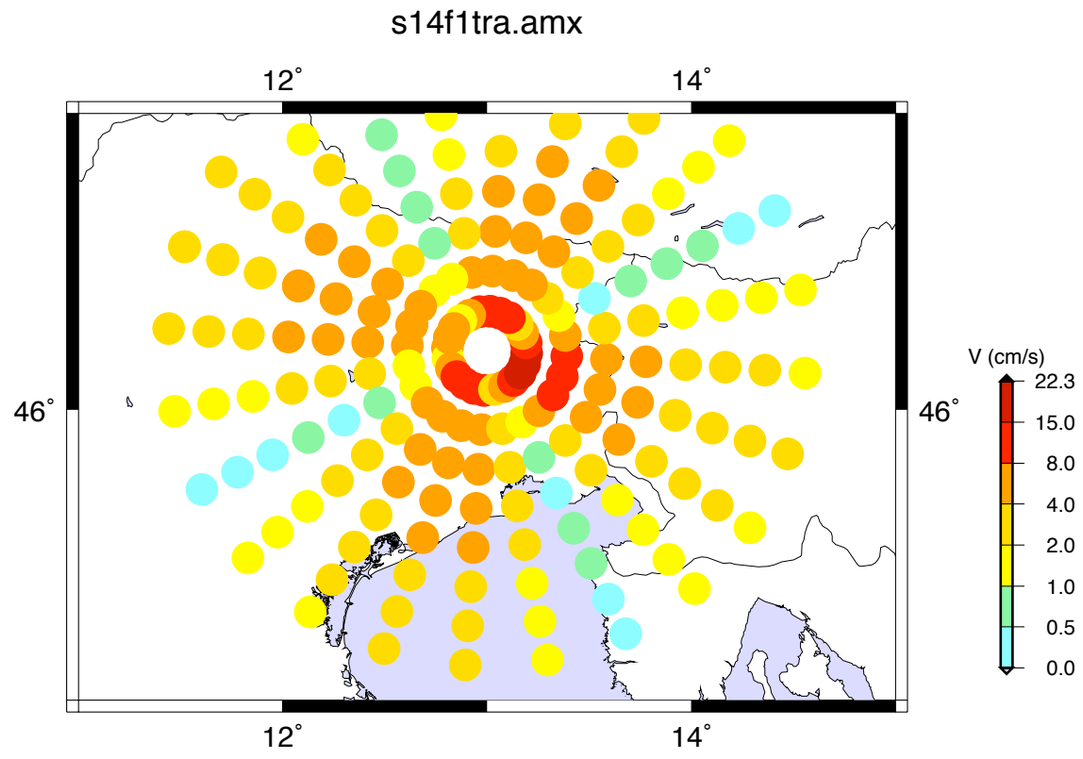


# Computer exercises - Synthetic seismograms

## Single event scenario




```
Parameter file for program eparatest
-------------------------------------------------------------------------------
test2                  Test label (root for output filenames - 13 chars max)
0                      Ref. box for values not listed below (0=no, 13 chars max)
z1d0014.spl            Love spectrum file
z1d0014.spr            Rayleigh spectrum file
2                      Motion (1=displ, 2=vel, 3=acc)
100                    Time length for plot seismograms (s)
1  13.0 46.2 289       Source (1=point, 2=extended), lon, lat, strike (Nord)
SRE 1   0 360 15       Strike (loop 0=no,1=yes, start, stop, step) (Degrees)
DIP 0  90  90 10       Dip (loop 0=no,1=yes, start, stop, step) (Degrees)
RAK 0 140  40 10       Rake (loop 0=no,1=yes, start, stop, step) (Degrees)
SDE 0  10   9  1       Source Depth (loop 0=no/1=yes, start, stop, step) (km)
EDI 2  15 120 15       Epic. Distance (loop 0=no/1=yes, start, stop, step) (km)
RDE 0   0   3  1       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  30  1       Interpolation (0-9) (flag 0=no,1=yes, start, stop, step)
MAG 0 6.0 7.0 .1       Magnitude (flag 0=no,1=yes, start, stop, step)
```



# Computer exercises - Synthetic seismograms

## Single event scenario

```
#!/bin/bash
set -e
echo $$ > eparajob.pid
date>test2parajob.pri
echo "Start of parajob job">>test2parajob.pri
cp syr.cntl.r syr.cntl
echo "Computing Radial Component..."
syr0048.out
date>>test2parajob.pri
echo "Radial Computed">>test2parajob.pri
cp syr.cntl.z syr.cntl
echo "Computing Vertical Component..."
syr0048.out
date>>test2parajob.pri
echo "Vertical Computed">>test2parajob.pri
cp syl.cntl.t syl.cntl
echo "Computing Transverse Component..."
syl0048.out
date>>test2parajob.pri
echo "Transverse Computed">>test2parajob.pri
date>>test2parajob.pri
echo "Scaling seismograms..."
efft.out
echo "Computing Resultant, NS and EW Components..."
rot.out
date>>test2parajob.pri
cat tmploop | awk '{ print $1,$2,$6 }'  > tmploopsel
grep amaxa test2f1.syr | awk '{ print $8 }'  > tmpr
grep amaxa test2f1.syz | awk '{ print $8 }'  > tmpz
grep amaxa test2f1.syl | awk '{ print $8 }'  > tmpl
grep amaxa test2f1.res | awk '{ print $9 }'  > tmpres
grep amaxa test2f1.sns | awk '{ print $8 }'  > tmpsns
grep amaxa test2f1.sew | awk '{ print $8 }'  > tmpsew
echo '#num sre edi  PGV rad   PGV ver   PGV tra   PGV res   PGV sns   PGV sew   dip=90.0 rak=140.0 sde=
10.000 rde=  0.000 mod=  0-  0\n\ int= 0 mag=6.0' > test2.sta
paste tmploopsel tmpr tmpz tmpl tmpres tmpsns tmpsew >> test2.sta
echo 'amaxa values' > test2f1rad.amx.tmp
echo '    2 0.1000E+01 : file type and normalizing factor' >> test2f1rad.amx.tmp
echo 'MINLATITUDE MAXLATITUDE : min. and max. latitude  of the area' >> test2f1rad.amx.tmp
echo 'MINLONGITUD MAXLONGITUD : min. and max. longitude of the area' >> test2f1rad.amx.tmp
echo '0.00000E+00             : cell size' >> test2f1rad.amx.tmp
echo 'amaxa values' > test2f1tra.amx.tmp
echo '    2 0.1000E+01 : file type and normalizing factor' >> test2f1tra.amx.tmp
echo 'MINLATITUDE MAXLATITUDE : min. and max. latitude  of the area' >> test2f1tra.amx.tmp
echo 'MINLONGITUD MAXLONGITUD : min. and max. longitude of the area' >> test2f1tra.amx.tmp
echo '0.00000E+00             : cell size' >> test2f1tra.amx.tmp
echo 'amaxa values' > test2f1ver.amx.tmp
echo '    2 0.1000E+01 : file type and normalizing factor' >> test2f1ver.amx.tmp
echo 'MINLATITUDE MAXLATITUDE : min. and max. latitude  of the area' >> test2f1ver.amx.tmp
echo 'MINLONGITUD MAXLONGITUD : min. and max. longitude of the area' >> test2f1ver.amx.tmp
echo '0.00000E+00             : cell size' >> test2f1ver.amx.tmp
echo 'amaxa values' > test2f1res.amx.tmp
echo '    2 0.1000E+01 : file type and normalizing factor' >> test2f1res.amx.tmp
echo 'MINLATITUDE MAXLATITUDE : min. and max. latitude  of the area' >> test2f1res.amx.tmp
echo 'MINLONGITUD MAXLONGITUD : min. and max. longitude of the area' >> test2f1res.amx.tmp
echo '0.00000E+00             : cell size' >> test2f1res.amx.tmp
echo 'amaxa values' > test2f1sns.amx.tmp
echo '    2 0.1000E+01 : file type and normalizing factor' >> test2f1sns.amx.tmp
echo 'MINLATITUDE MAXLATITUDE : min. and max. latitude  of the area' >> test2f1sns.amx.tmp
echo 'MINLONGITUD MAXLONGITUD : min. and max. longitude of the area' >> test2f1sns.amx.tmp
echo '0.00000E+00             : cell size' >> test2f1sns.amx.tmp
echo 'amaxa values' > test2f1sew.amx.tmp
echo '    2 0.1000E+01 : file type and normalizing factor' >> test2f1sew.amx.tmp
echo 'MINLATITUDE MAXLATITUDE : min. and max. latitude  of the area' >> test2f1sew.amx.tmp
echo 'MINLONGITUD MAXLONGITUD : min. and max. longitude of the area' >> test2f1sew.amx.tmp
echo '0.00000E+00             : cell size' >> test2f1sew.amx.tmp
paste tmpmap tmpr >> test2f1rad.amx.tmp
paste tmpmap tmpl >> test2f1tra.amx.tmp
paste tmpmap tmpz >> test2f1ver.amx.tmp
paste tmpmap tmpres >> test2f1res.amx.tmp
paste tmpmap tmpsns >> test2f1sns.amx.tmp
paste tmpmap tmpsew >> test2f1sew.amx.tmp
MINLG=`(minmax -C tmpmap | awk '{ print $1 }')`
MAXLG=`(minmax -C tmpmap | awk '{ print $2 }')`
MINLT=`(minmax -C tmpmap | awk '{ print $3 }')`
MAXLT=`(minmax -C tmpmap | awk '{ print $4 }')`
sed 's/MINLATITUDE/'`echo $MINLT`'/g' test2f1rad.amx.tmp > test2f1rad.amx.tmp1
sed 's/MAXLATITUDE/'`echo $MAXLT`'/g' test2f1rad.amx.tmp1 > test2f1rad.amx.tmp2
sed 's/MINLONGITUD/'`echo $MINLG`'/g' test2f1rad.amx.tmp2 > test2f1rad.amx.tmp3
sed 's/MAXLONGITUD/'`echo $MAXLG`'/g' test2f1rad.amx.tmp3 > test2f1rad.amx
sed 's/MINLATITUDE/'`echo $MINLT`'/g' test2f1tra.amx.tmp > test2f1tra.amx.tmp1
sed 's/MAXLATITUDE/'`echo $MAXLT`'/g' test2f1tra.amx.tmp1 > test2f1tra.amx.tmp2
sed 's/MINLONGITUD/'`echo $MINLG`'/g' test2f1tra.amx.tmp2 > test2f1tra.amx.tmp3
sed 's/MAXLONGITUD/'`echo $MAXLG`'/g' test2f1tra.amx.tmp3 > test2f1tra.amx
sed 's/MINLATITUDE/'`echo $MINLT`'/g' test2f1ver.amx.tmp > test2f1ver.amx.tmp1
sed 's/MAXLATITUDE/'`echo $MAXLT`'/g' test2f1ver.amx.tmp1 > test2f1ver.amx.tmp2
sed 's/MINLONGITUD/'`echo $MINLG`'/g' test2f1ver.amx.tmp2 > test2f1ver.amx.tmp3
sed 's/MAXLONGITUD/'`echo $MAXLG`'/g' test2f1ver.amx.tmp3 > test2f1ver.amx
sed 's/MINLATITUDE/'`echo $MINLT`'/g' test2f1res.amx.tmp > test2f1res.amx.tmp1
sed 's/MAXLATITUDE/'`echo $MAXLT`'/g' test2f1res.amx.tmp1 > test2f1res.amx.tmp2
sed 's/MINLONGITUD/'`echo $MINLG`'/g' test2f1res.amx.tmp2 > test2f1res.amx.tmp3
sed 's/MAXLONGITUD/'`echo $MAXLG`'/g' test2f1res.amx.tmp3 > test2f1res.amx
sed 's/MINLATITUDE/'`echo $MINLT`'/g' test2f1sns.amx.tmp > test2f1sns.amx.tmp1
sed 's/MAXLATITUDE/'`echo $MAXLT`'/g' test2f1sns.amx.tmp1 > test2f1sns.amx.tmp2
sed 's/MINLONGITUD/'`echo $MINLG`'/g' test2f1sns.amx.tmp2 > test2f1sns.amx.tmp3
sed 's/MAXLONGITUD/'`echo $MAXLG`'/g' test2f1sns.amx.tmp3 > test2f1sns.amx
sed 's/MINLATITUDE/'`echo $MINLT`'/g' test2f1sew.amx.tmp > test2f1sew.amx.tmp1
sed 's/MAXLATITUDE/'`echo $MAXLT`'/g' test2f1sew.amx.tmp1 > test2f1sew.amx.tmp2
sed 's/MINLONGITUD/'`echo $MINLG`'/g' test2f1sew.amx.tmp2 > test2f1sew.amx.tmp3
sed 's/MAXLONGITUD/'`echo $MAXLG`'/g' test2f1sew.amx.tmp3 > test2f1sew.amx
rm -f tmpmap
rm -f test2f1rad.amx.tmp test2f1rad.amx.tmp1 test2f1rad.amx.tmp2 test2f1rad.amx.tmp3
rm -f test2f1tra.amx.tmp test2f1tra.amx.tmp1 test2f1tra.amx.tmp2 test2f1tra.amx.tmp3
rm -f test2f1ver.amx.tmp test2f1ver.amx.tmp1 test2f1ver.amx.tmp2 test2f1ver.amx.tmp3
rm -f test2f1res.amx.tmp test2f1res.amx.tmp1 test2f1res.amx.tmp2 test2f1res.amx.tmp3
rm -f test2f1sns.amx.tmp test2f1sns.amx.tmp1 test2f1sns.amx.tmp2 test2f1sns.amx.tmp3
rm -f test2f1sew.amx.tmp test2f1sew.amx.tmp1 test2f1sew.amx.tmp2 test2f1sew.amx.tmp3
hazcpt.out
sh hazgmt.sh test2f1rad.amx test2f1tra.amx test2f1ver.amx test2f1res.amx test2f1sns.amx test2f1sew.amx
minmax -C tmpr | awk '{ print $2 }' > tmpsort
minmax -C tmpz | awk '{ print $2 }' >> tmpsort
minmax -C tmpl | awk '{ print $2 }' >> tmpsort
minmax -C tmpres | awk '{ print $2 }' >> tmpsort
minmax -C tmpsns | awk '{ print $2 }' >> tmpsort
minmax -C tmpsew | awk '{ print $2 }' >> tmpsort
MAX=`(cat tmpsort | sort -rn | head -1 )`
sed 's/XXX/set yrange [0:'`echo $MAX`']/g' test2.plot > test2.gplot
rm -f tmploop tmploopsel tmpr tmpz tmpl tmpres tmpsns tmpsew tmpsort *.plot
gnuplot test2.gplot
echo " "
cp sisplots.par.rad sisplots.par
sisplots.pl
cp sisplots.par.ver sisplots.par
sisplots.pl
cp sisplots.par.tra sisplots.par
sisplots.pl
echo "*** To plot the seismograms: gs test2.sis.*.ps"
echo "*** To plot the peak values: gs test2.ps"
echo " "
echo "*** To plot the maps: gs test2f1*.amx.ps"
```

# Computer exercises - Synthetic seismograms

## Soil categories

A - *Formazioni litoidi o suoli omogenei molto rigidi* caratterizzati da valori di $V_{S30}$ superiori a 800 m/s, comprendenti eventuali strati di alterazione superficiale di spessore massimo pari a 5 m.

B - *Depositi di sabbie o ghiaie molto addensate o argille molto consistenti*, con spessori di diverse decine di metri, caratterizzati da un graduale miglioramento delle proprietà meccaniche con la profondità e da valori di $V_{S30}$ compresi tra 360 m/s e 800 m/s (ovvero resistenza penetrometrica $N_{SPT} > 50$, o coesione non drenata $c_u$>250 kPa).

C - *Depositi di sabbie e ghiaie mediamente addensate, o di argille di media consistenza*, con spessori variabili da diverse decine fino a centinaia di metri, caratterizzati da valori di $V_{S30}$ compresi tra 180 e 360 m/s ($15 < N_{SPT} < 50$, 70 <$c_u$<250 kPa).

D - *Depositi di terreni granulari da sciolti a poco addensati oppure coesivi da poco a mediamente consistenti* , caratterizzati da valori di $V_{S30} < 180$ m/s ($N_{SPT} < 15$, $c_u$<70 kPa).

E - *Profili di terreno costituiti da strati superficiali alluvionali*, con valori di $V_{S30}$ simili a quelli dei tipi C o D e spessore compreso tra 5 e 20 m, giacenti su di un substrato di materiale più rigido con $V_{S30} > 800$ m/s.

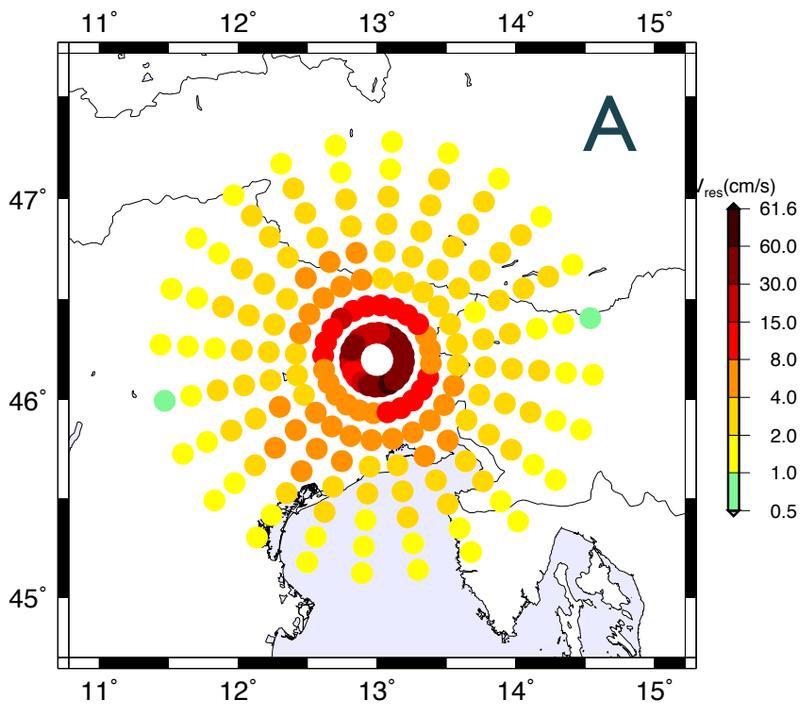
In aggiunta a queste categorie, per le quali nel punto 3.2 vengono definite le azioni sismiche da considerare nella progettazione, se ne definiscono altre due, per le quali sono richiesti studi speciali per la definizione dell'azione sismica da considerare:

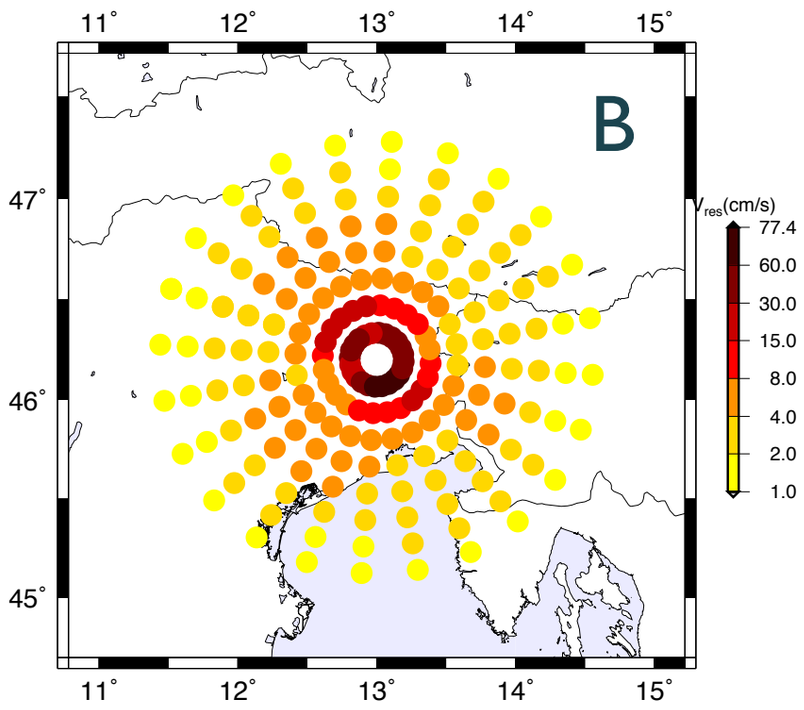
S1 - Depositi costituiti da, o che includono, uno strato spesso almeno 10 m di argille/limi di bassa consistenza, con elevato indice di plasticità (PI > 40) e contenuto di acqua, caratterizzati da valori di $V_{S30} < 100$ m/s ($10 < c_u < 20$ kPa)

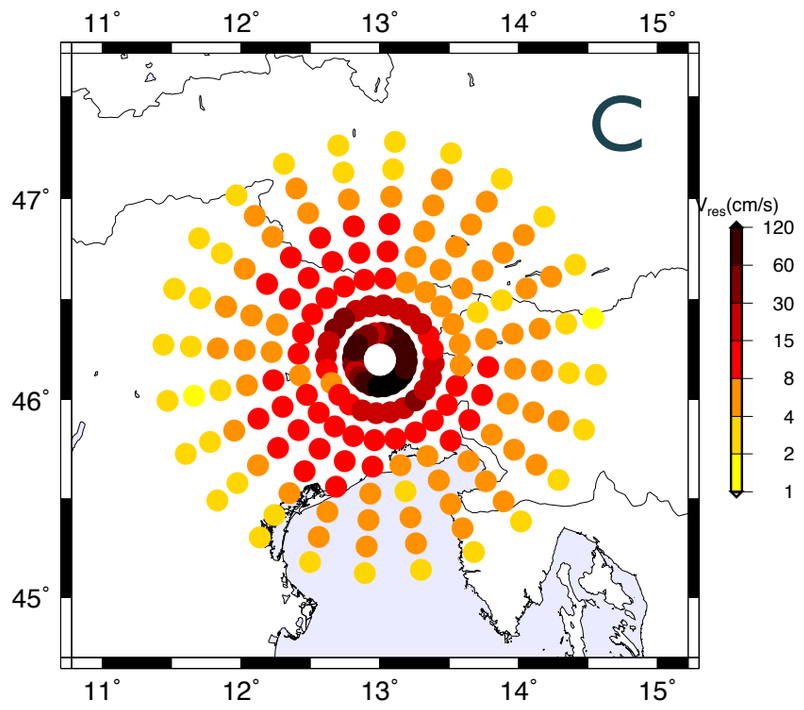
S2 - Depositi di terreni soggetti a liquefazione, di argille sensitive, o qualsiasi altra categoria di terreno non classificabile nei tipi precedenti

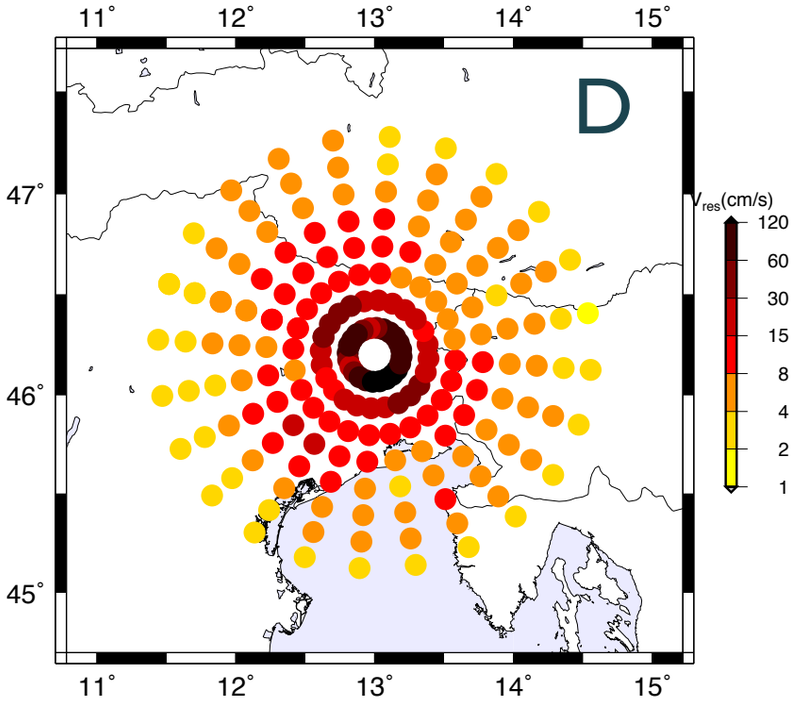
# Computer exercises - Synthetic seismograms

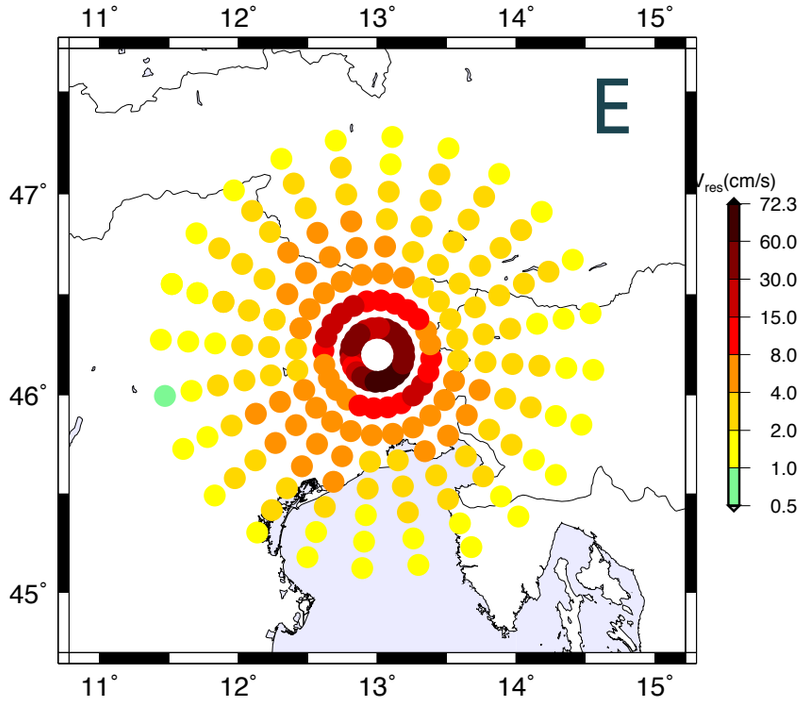
- Single event scenario, parametric tests for soils A,B,C,D,E - low Q



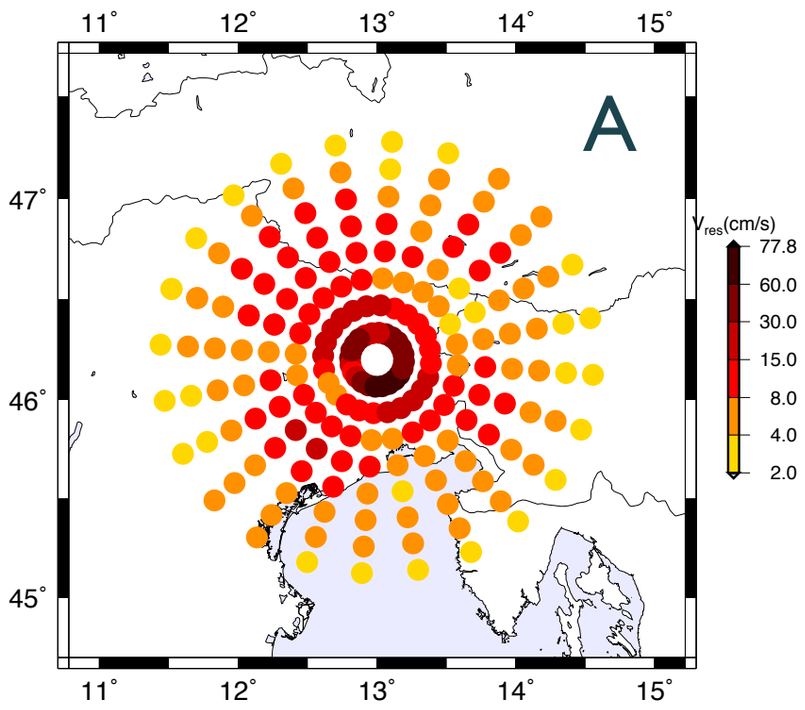



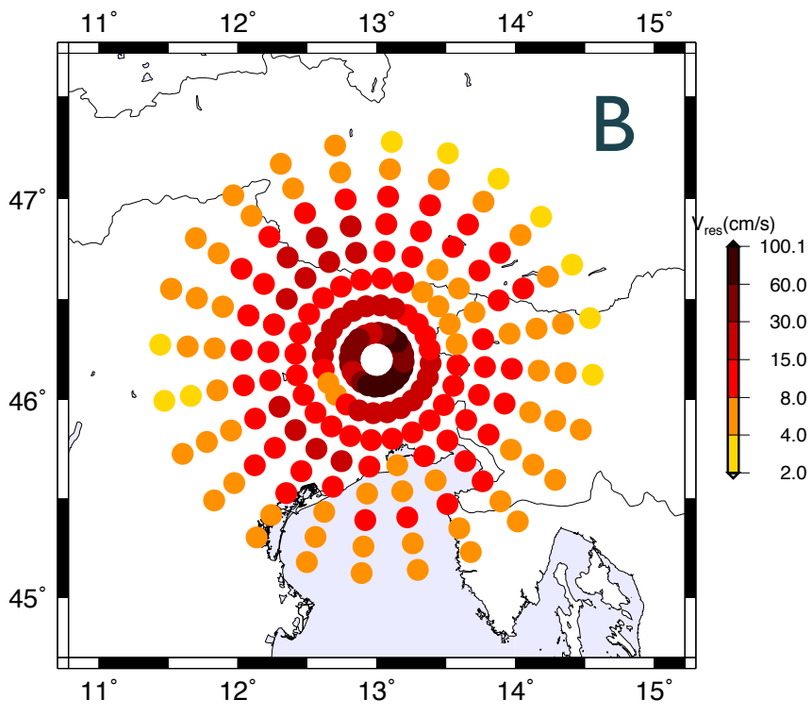



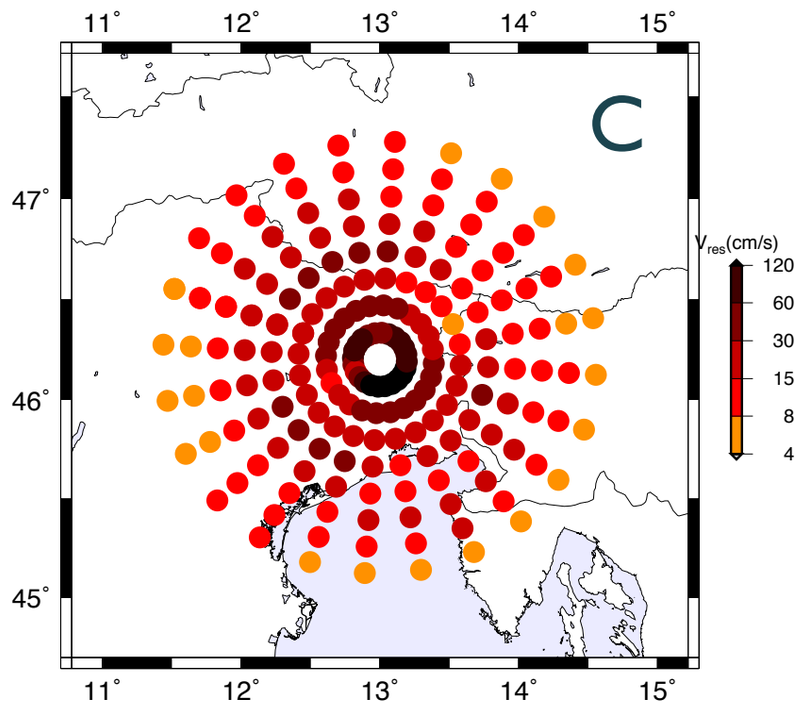



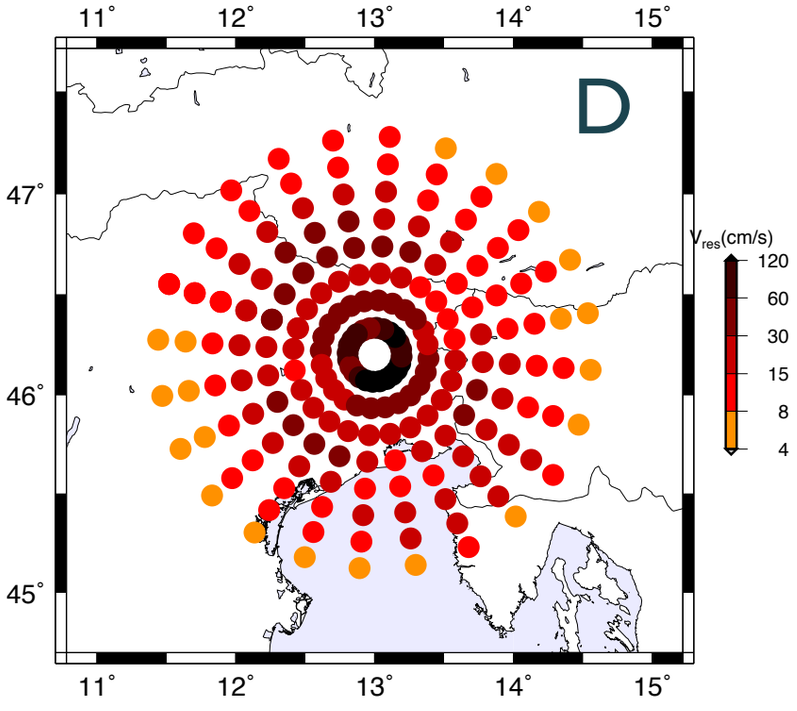
# Computer exercises - Synthetic seismograms

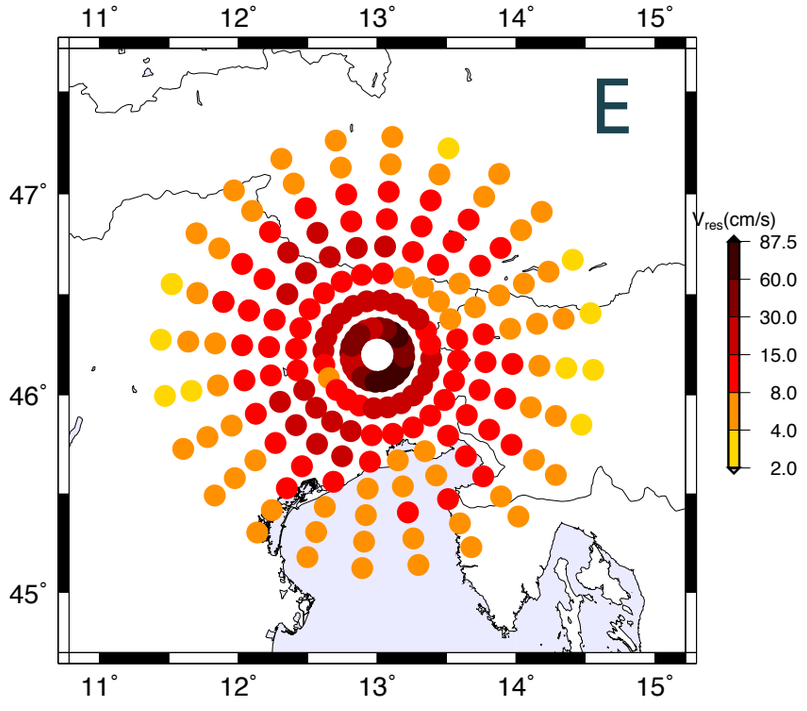
- Single event scenario, parametric tests for soils A,B,C,D,E - high Q



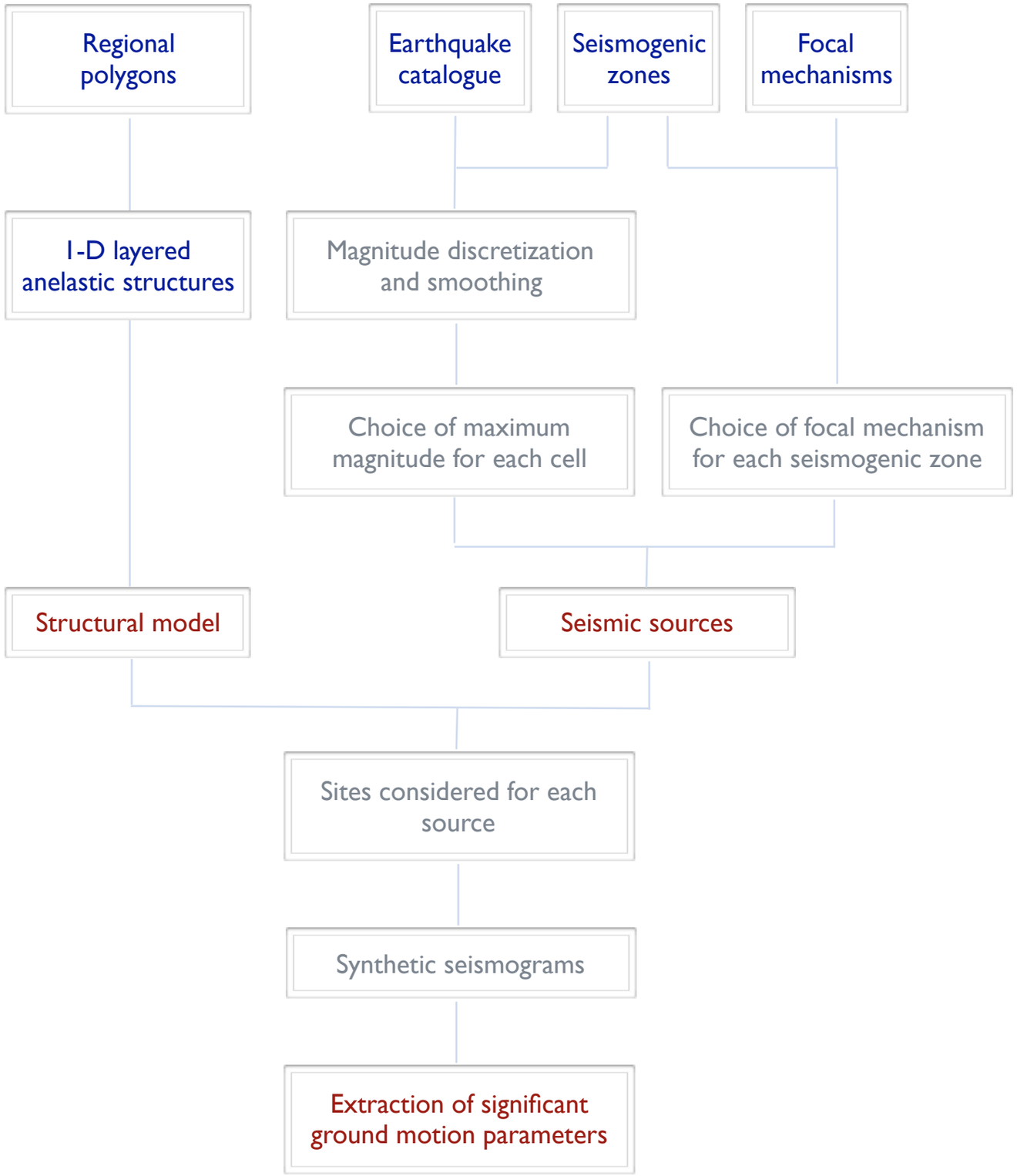
# Seismic hazard maps in Italy

## The neo-deterministic approach...

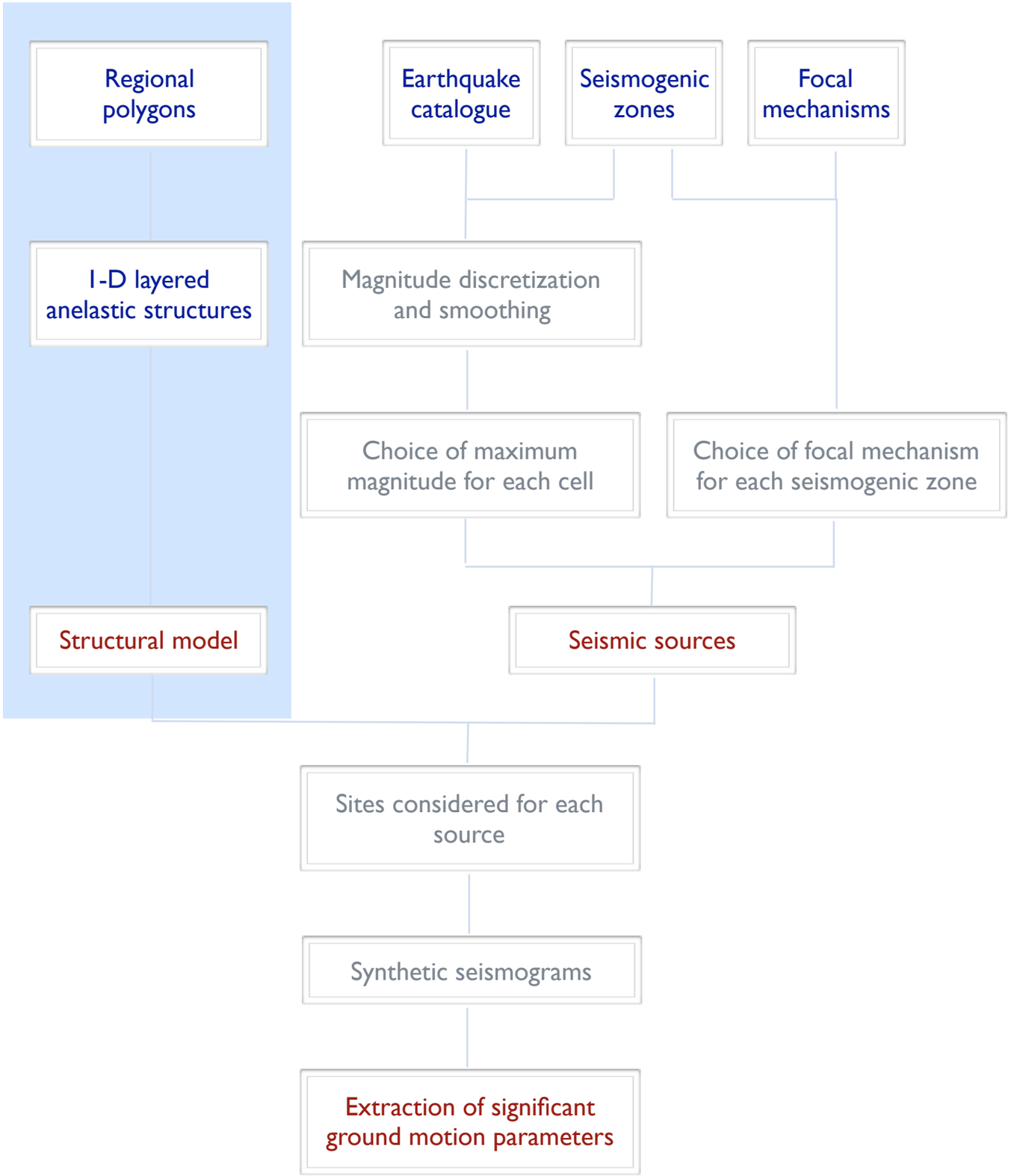
# Neo-deterministic approach

- Collection of available data
  - Structural properties
  - Historical seismicity
  - Tectonic regime
  - Seismogenic zones
  - ...
- Modelling of ground shaking scenarios
  - Regional scale: on a grid of sites covering the studied area
  - Local scale: along laterally heterogeneous profiles

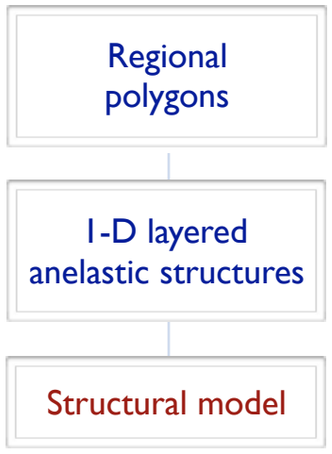
# Regional scale - Flow chart



# Regional scale - Structural model

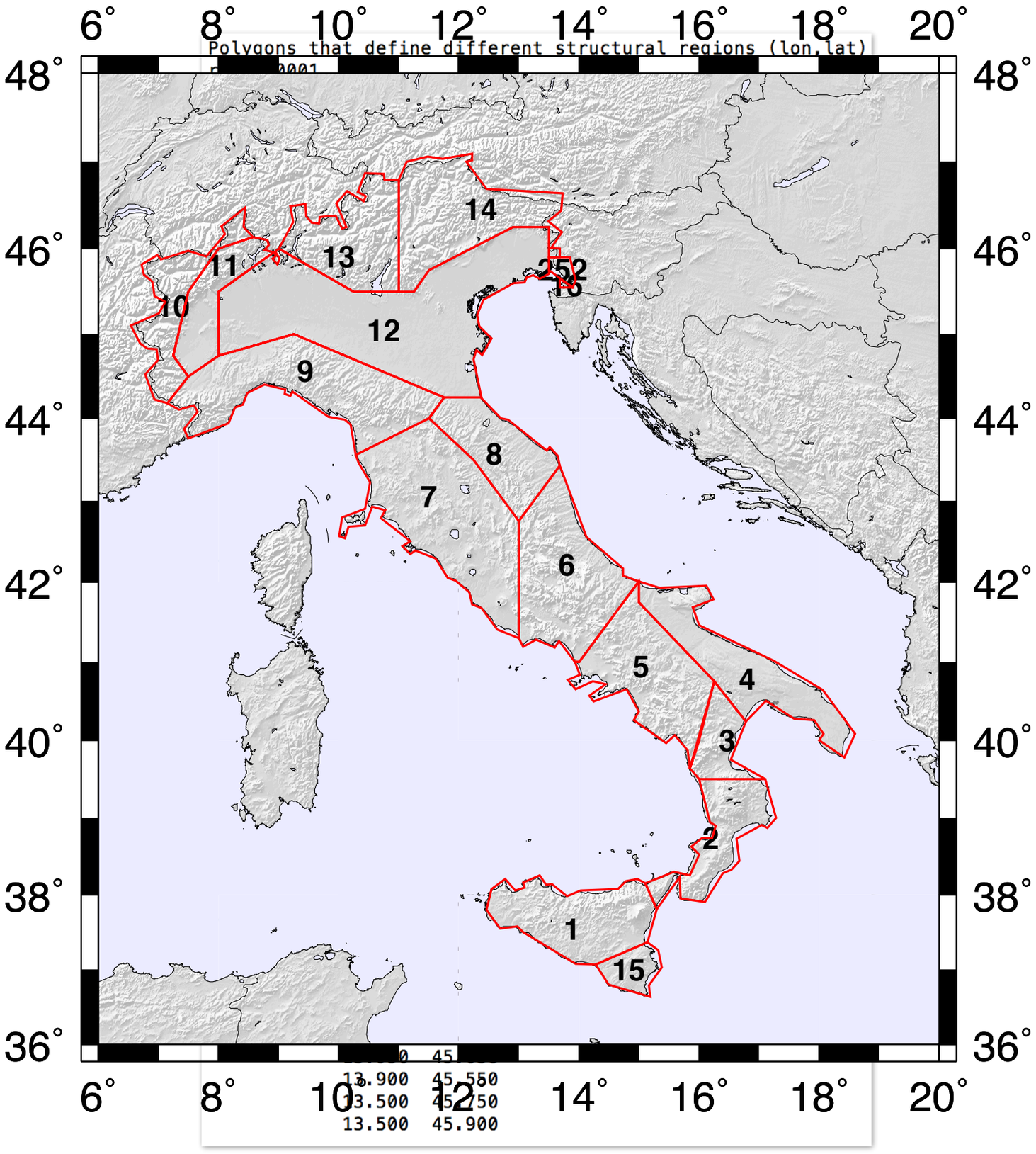


# Regional scale - Structural model



# Regional scale - Structural model

- Regional polygons
- 1-D layered anelastic structures
- Structural model



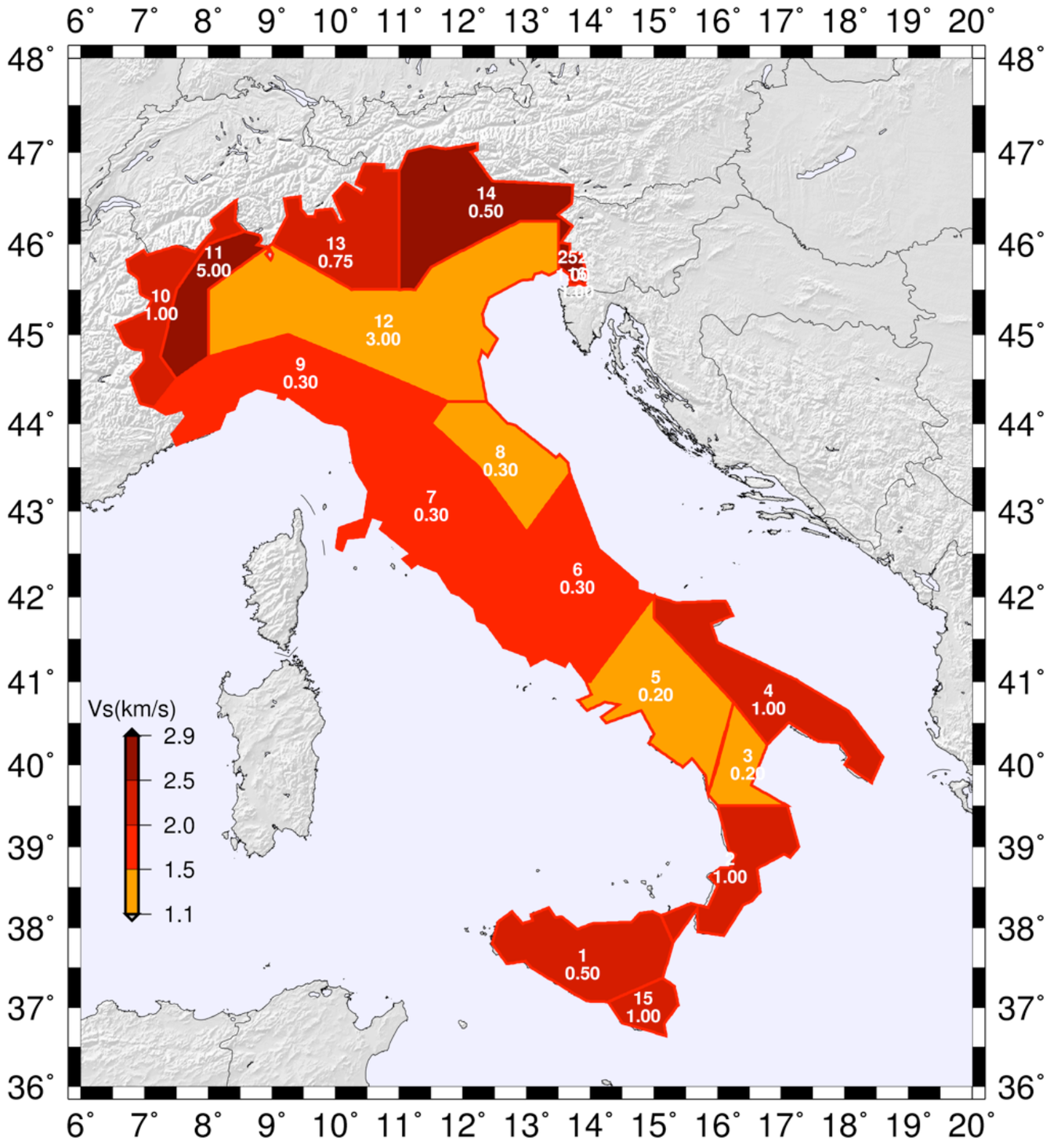
# Regional scale - Structural model

- Regional polygons
- 1-D layered anelastic structures
- Structural model

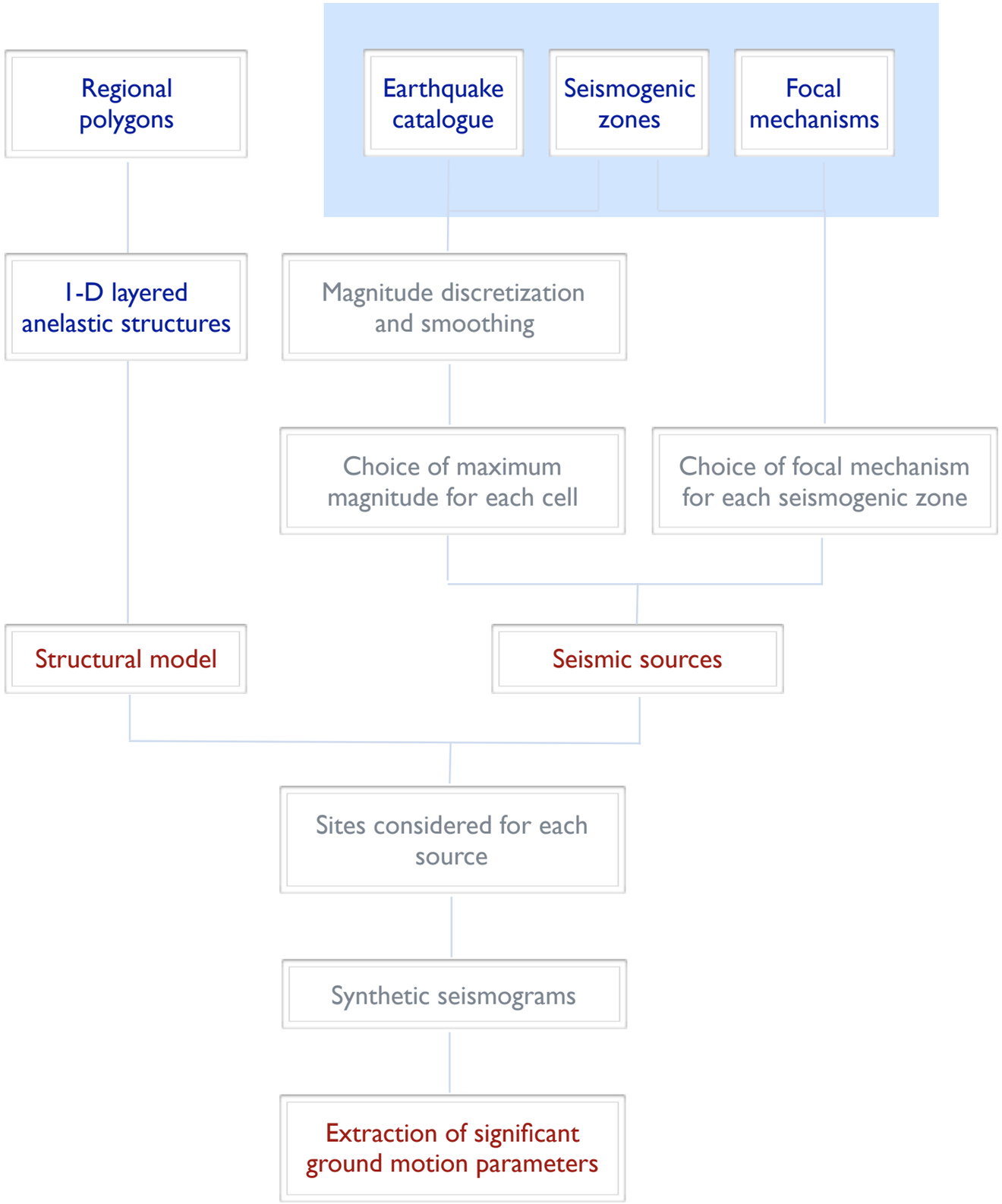
| thk(km) | rho | Vp(km/s) | Vs(km/s) | Qp | Qs | depth(km) | layer |
|---|---|---|---|---|---|---|---|
| 0.5000 | 2.300 | 3.800000 | 2.200000 | 660.00 | 300.00 | 0.50000 | 1 |
| 0.5000 | 2.300 | 3.900000 | 2.250000 | 660.00 | 300.00 | 1.00000 | 2 |
| 1.0000 | 2.450 | 4.000000 | 2.300000 | 660.00 | 300.00 | 2.00000 | 3 |
| 4.0000 | 2.450 | 4.800000 | 2.700000 | 660.00 | 300.00 | 6.00000 | 4 |
| 3.0000 | 2.600 | 5.900000 | 3.350000 | 660.00 | 300.00 | 9.00000 | 5 |
| 5.0000 | 2.700 | 6.500000 | 3.700000 | 660.00 | 300.00 | 14.00000 | 6 |
| 6.0000 | 2.800 | 7.000000 | 4.000000 | 660.00 | 300.00 | 20.00000 | 7 |
| 8.0000 | 2.800 | 6.700000 | 3.750200 | 660.00 | 300.00 | 28.00000 | 8 |
| 3.0000 | 2.850 | 6.700000 | 3.750300 | 660.00 | 300.00 | 31.00000 | 9 |
| 1.0000 | 2.900 | 7.000000 | 4.000000 | 660.00 | 300.00 | 32.00000 | 10 |
| 68.0000 | 3.350 | 8.000000 | 4.500000 | 660.00 | 300.00 | 100.00000 | 11 |
| 100.0000 | 3.400 | 8.000000 | 4.150600 | 220.00 | 100.00 | 200.00000 | 12 |
| 10.0000 | 3.450 | 8.200000 | 4.400000 | 220.00 | 100.00 | 210.00000 | 13 |
| 10.0000 | 3.450 | 8.250000 | 4.450000 | 220.00 | 100.00 | 220.00000 | 14 |
| 10.0000 | 3.450 | 8.300000 | 4.500000 | 220.00 | 100.00 | 230.00000 | 15 |
| 10.0000 | 3.450 | 8.350000 | 4.550000 | 220.00 | 100.00 | 240.00000 | 16 |
| 10.0000 | 3.450 | 8.400000 | 4.600000 | 220.00 | 100.00 | 250.00000 | 17 |
| 60.0000 | 3.500 | 8.400000 | 4.600100 | 220.00 | 100.00 | 310.00000 | 18 |
| 9.0000 | 3.500 | 8.700000 | 4.750000 | 330.00 | 150.00 | 319.00000 | 19 |
| 10.0000 | 3.520 | 8.740000 | 4.750100 | 330.00 | 150.00 | 329.00000 | 20 |
| ... | | | | | | | |
| ... | | | | | | | |
| ... | | | | | | | |
| 25.0000 | 3.950 | 9.576000 | 5.285000 | 330.00 | 150.00 | 565.00000 | 30 |
| 25.0000 | 4.000 | 9.630000 | 5.313000 | 330.00 | 150.00 | 590.00000 | 31 |
| 25.0000 | 4.050 | 9.683000 | 5.340000 | 330.00 | 150.00 | 615.00000 | 32 |
| 25.0000 | 4.100 | 9.736000 | 5.367000 | 374.00 | 170.00 | 640.00000 | 33 |
| 25.0000 | 4.200 | 9.782000 | 5.390000 | 440.00 | 200.00 | 665.00000 | 34 |
| 25.0000 | 4.250 | 10.014000 | 5.518000 | 506.00 | 230.00 | 690.00000 | 35 |
| 25.0000 | 4.300 | 10.180000 | 5.630000 | 572.00 | 260.00 | 715.00000 | 36 |
| 25.0000 | 4.350 | 10.190000 | 5.746000 | 638.00 | 290.00 | 740.00000 | 37 |
| 25.0000 | 4.400 | 10.492000 | 5.850000 | 704.00 | 320.00 | 765.00000 | 38 |
| 25.0000 | 4.410 | 10.677000 | 5.950000 | 770.00 | 350.00 | 790.00000 | 39 |
| 25.0000 | 4.420 | 10.852000 | 6.044000 | 836.00 | 380.00 | 815.00000 | 40 |
| 25.0000 | 4.425 | 11.025000 | 6.140000 | 902.00 | 410.00 | 840.00000 | 41 |
| 25.0000 | 4.435 | 11.180000 | 6.230000 | 968.00 | 440.00 | 865.00000 | 42 |
| 25.0000 | 4.450 | 11.224000 | 6.250000 | 1045.00 | 475.00 | 890.00000 | 43 |
| 25.0000 | 4.475 | 11.267000 | 6.275000 | 1100.00 | 500.00 | 915.00000 | 44 |
| 25.0000 | 4.500 | 11.310000 | 6.297000 | 1166.00 | 530.00 | 940.00000 | 45 |
| 25.0000 | 4.525 | 11.350000 | 6.322000 | 1232.00 | 560.00 | 965.00000 | 46 |
| 25.0000 | 4.550 | 11.392000 | 6.340000 | 1320.00 | 600.00 | 990.00000 | 47 |
| 25.0000 | 4.575 | 11.434000 | 6.360000 | 1375.00 | 625.00 | 1015.00000 | 48 |
| 25.0000 | 4.600 | 11.476000 | 6.375000 | 1452.00 | 660.00 | 1040.00000 | 49 |
| 25.0000 | 4.630 | 11.518000 | 6.390000 | 1507.00 | 685.00 | 1065.00000 | 50 |
| 25.0000 | 4.660 | 11.560000 | 6.405000 | 1584.00 | 720.00 | 1090.00000 | 51 |
| 25.0000 | 4.680 | 11.600000 | 6.421000 | 1650.00 | 750.00 | 1115.00000 | 52 |

# Regional scale - Structural model

- Regional polygons
- 1-D layered anelastic structures
- Structural model



# Regional scale - Sources

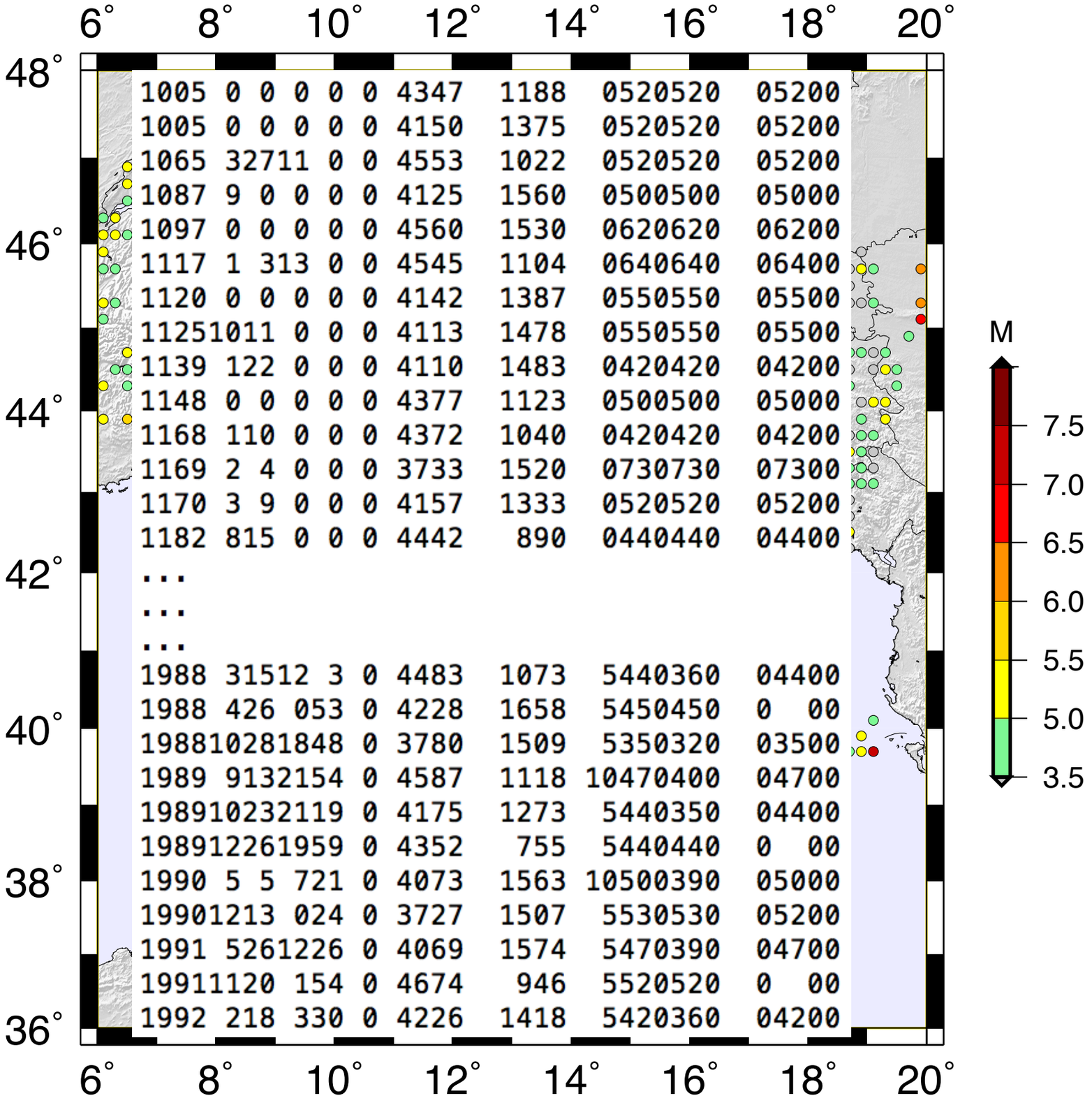


# Regional scale - Sources

Earthquake catalogue

Seismogenic zones

Focal mechanisms

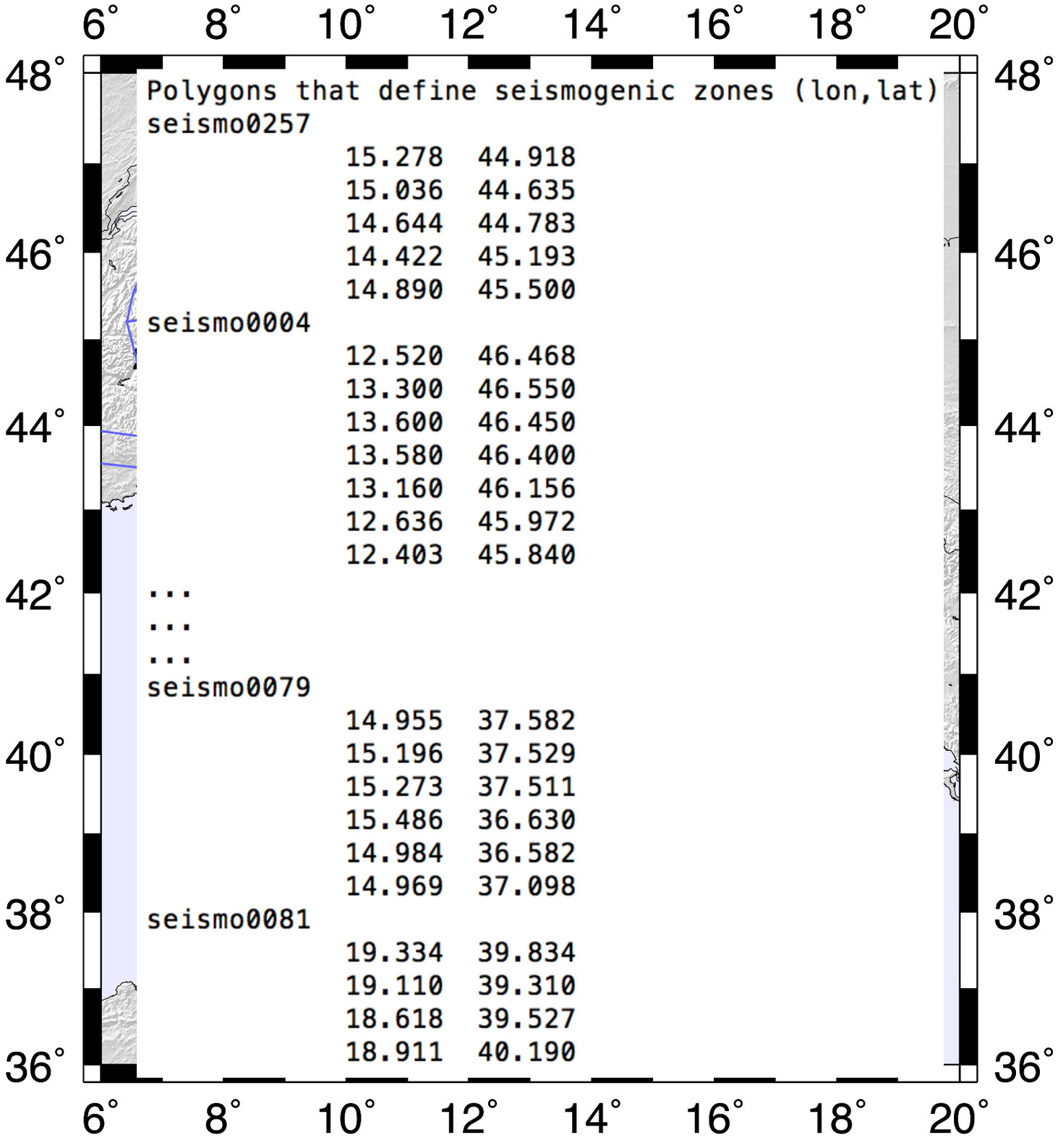


# Regional scale - Sources

Earthquake catalogue

Seismogenic zones

Focal mechanisms

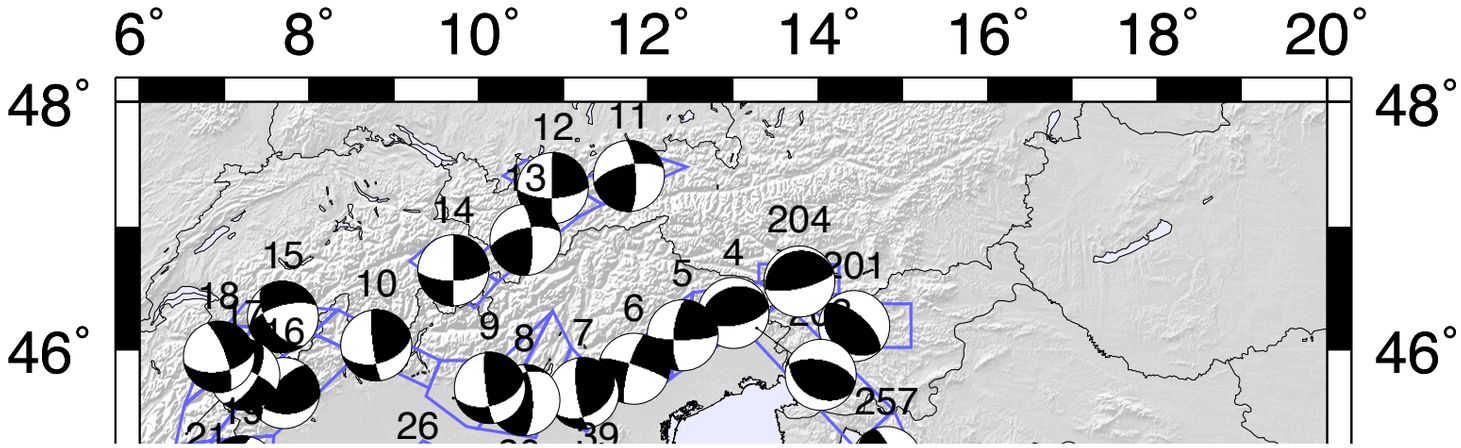


# Regional scale - Sources

Earthquake catalogue

Seismogenic zones

Focal mechanisms

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NUMBEM M00 SF REFE DURA F2 M0XX ER1 M0YY ER2 M0ZZ ER3 M0XY ER4 M0XZ ER5 M0YZ ER6
NUMBET HDR SF M0 TVAL TD TAZ NVAL ND NAZ PVAL PD PAZ AST AD ARA BST BD BRA REFER
NUMBEU SF SMRR ER1 SMTT ER2 SMFF ER3 SMRT ER4 SMRF ER5 SMTF ER6
-----------------------------------------------------------------------------
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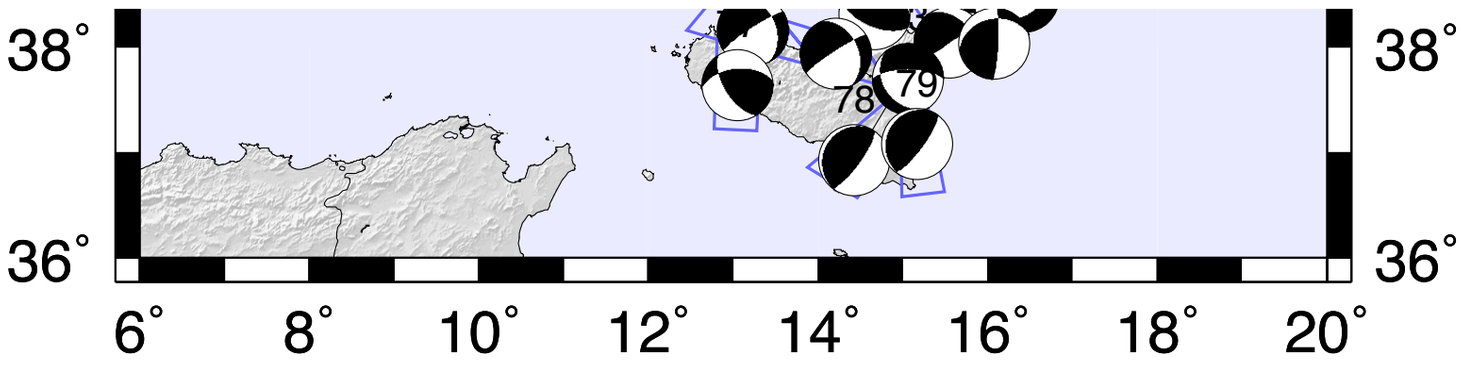
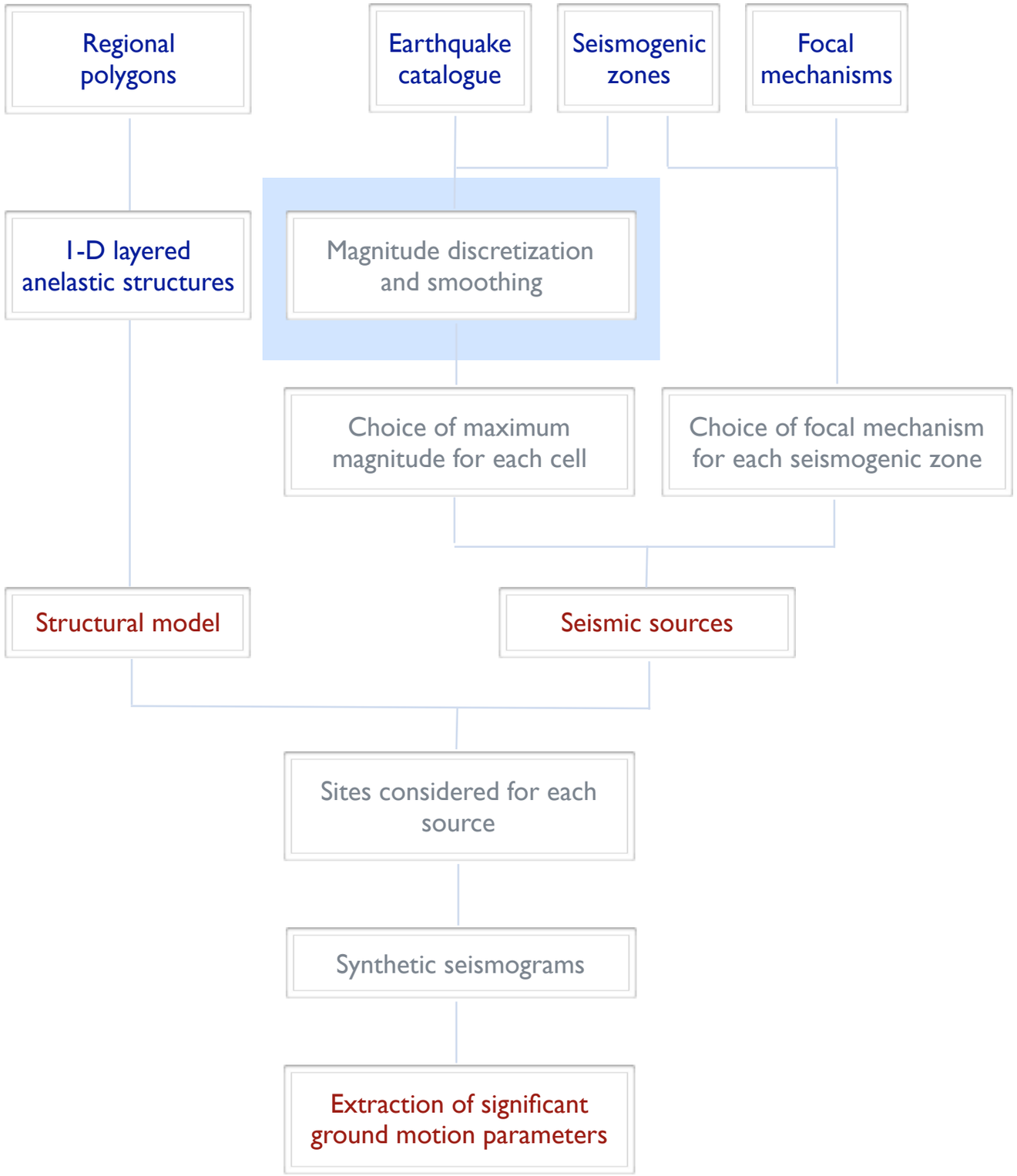
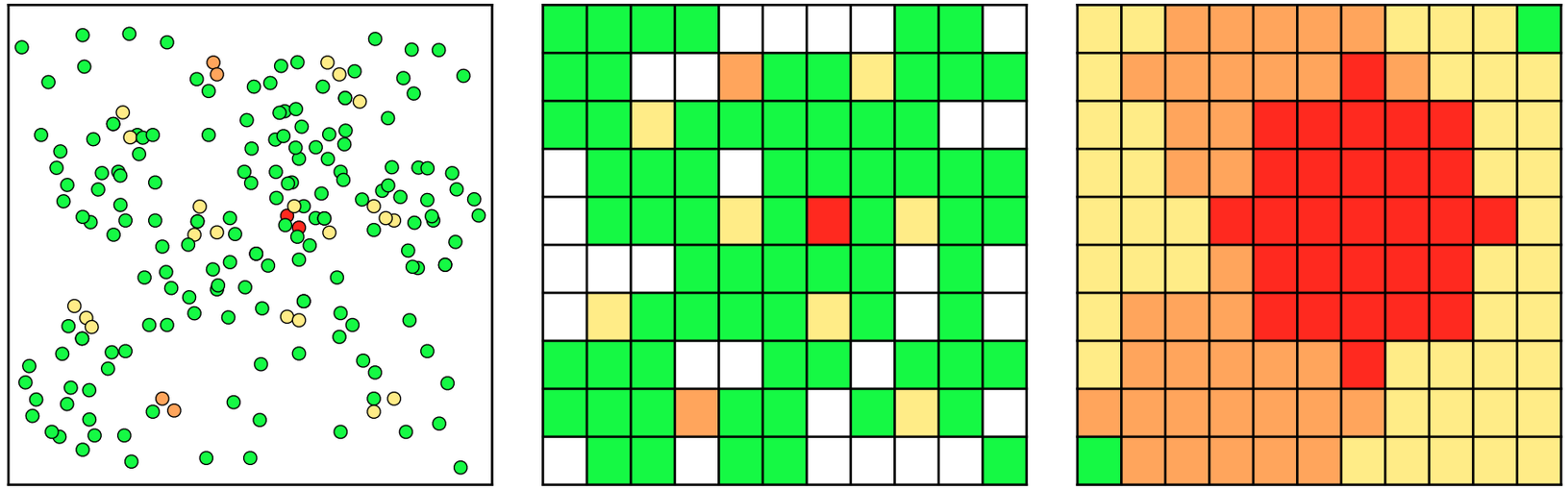


# Regional scale - Sources

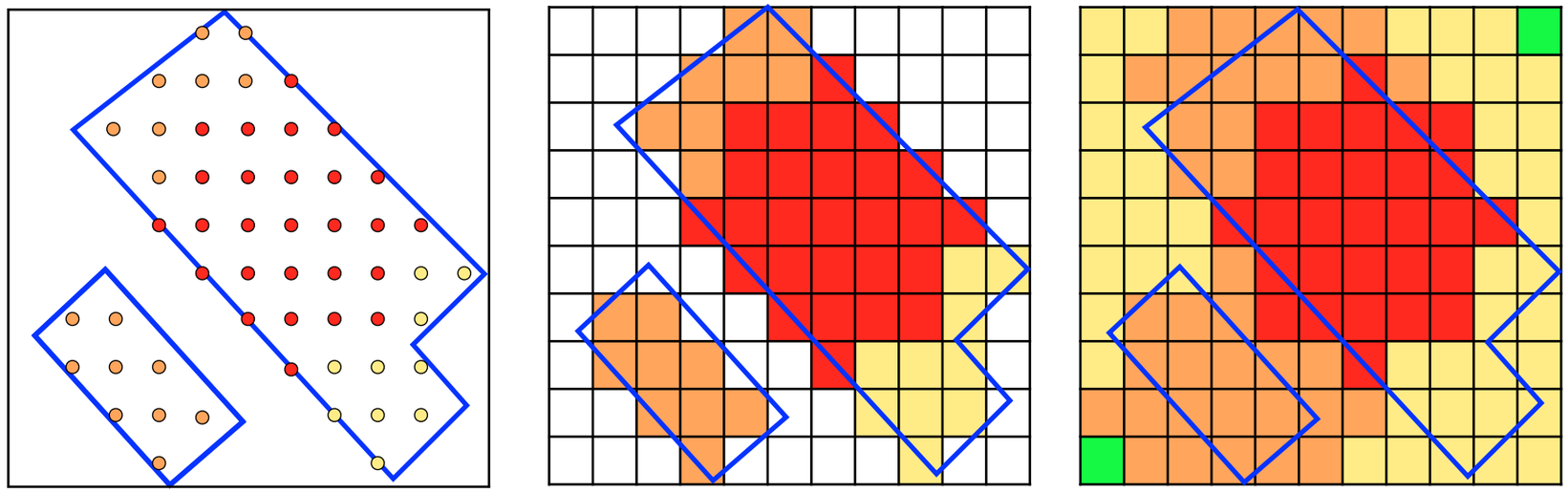


# Regional scale - Sources

Seismicity → 1 - Discretization → 2 - Smoothing



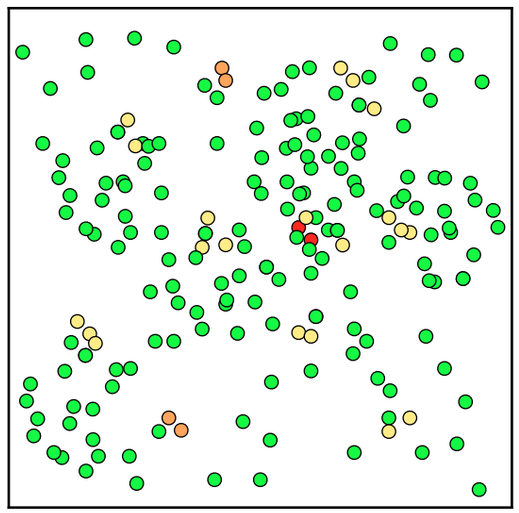
Magnitude discretization and smoothing

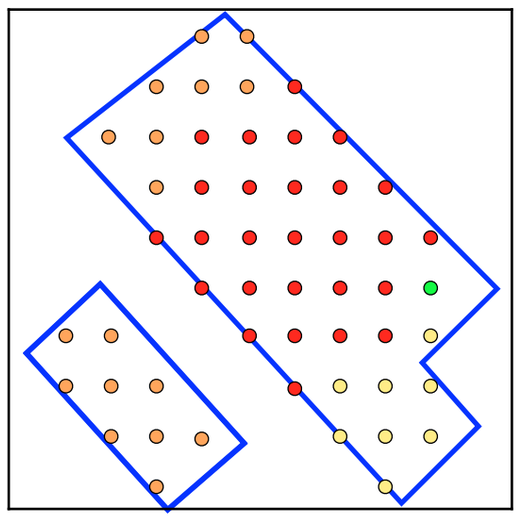


5 - Sources ← 4 - Truncation ← 3 - Seismogenic zone

# Regional scale - Sources

Seismicity



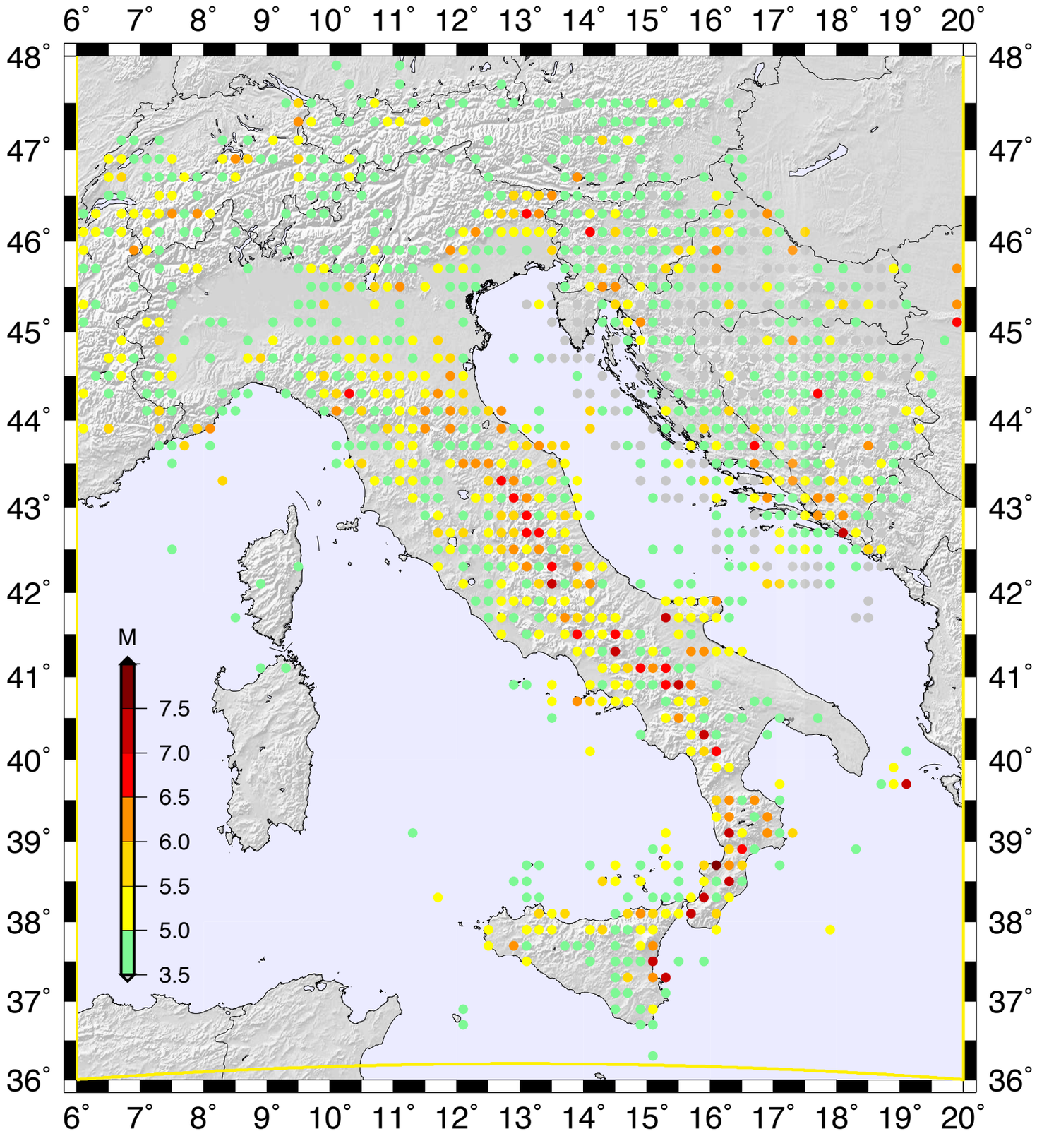


Sources

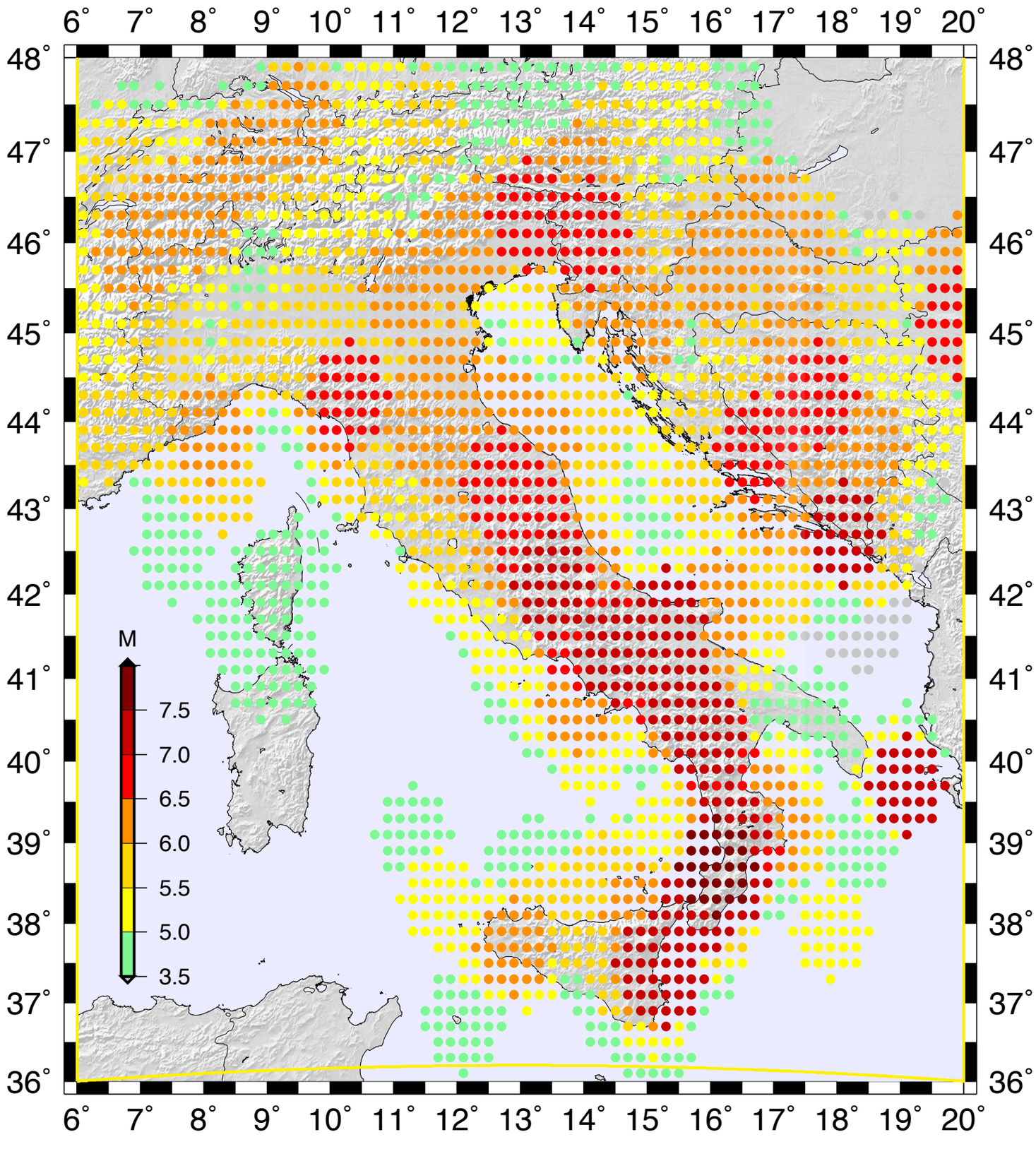
Magnitude discretization and smoothing

- Why do we do this?
  - To account for mislocations of events in the catalogue
  - To account (roughly) for fault dimensions
  - To account for the location of future events
  - To be conservative...

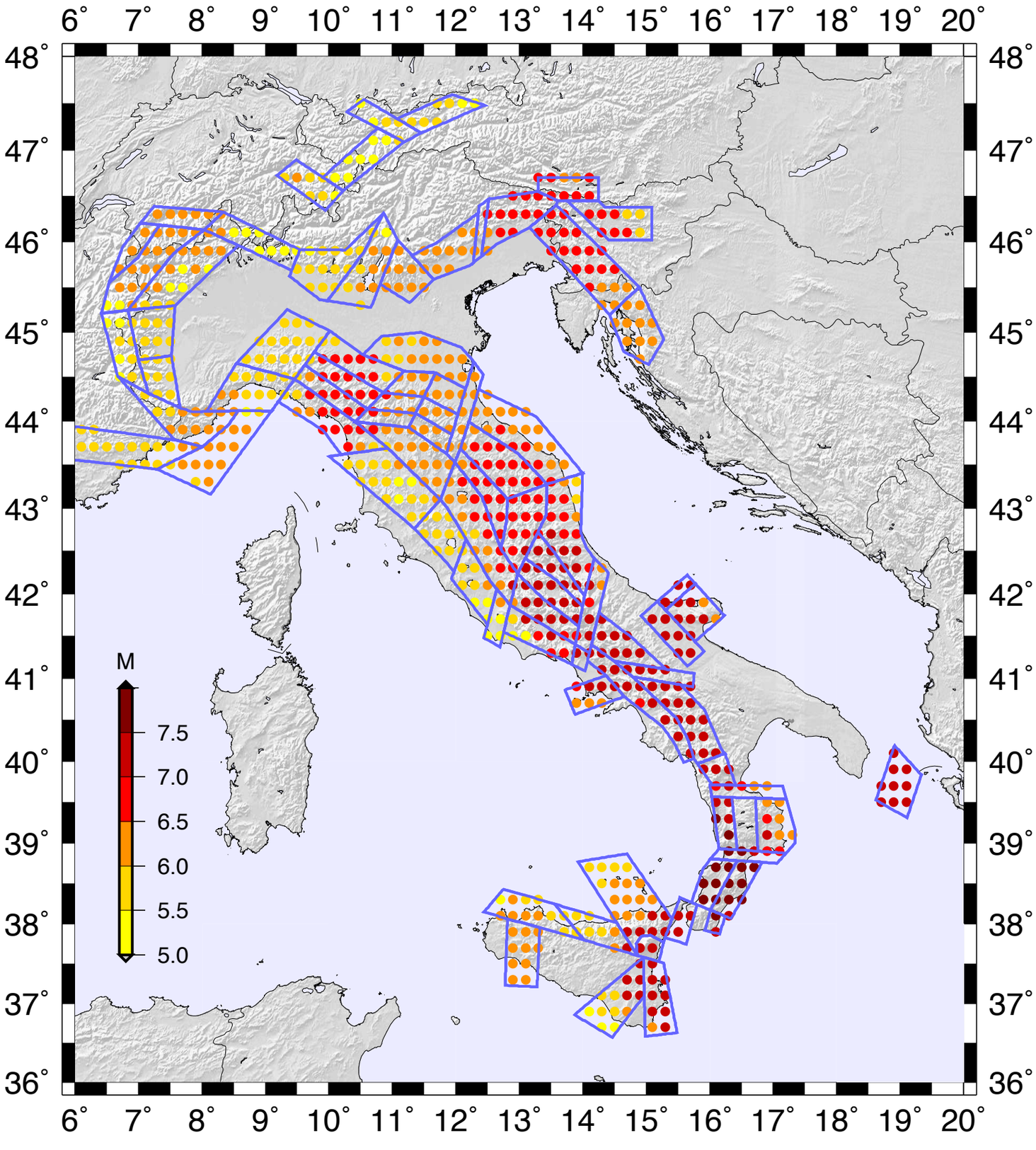
# Regional scale - Discretized Magnitude



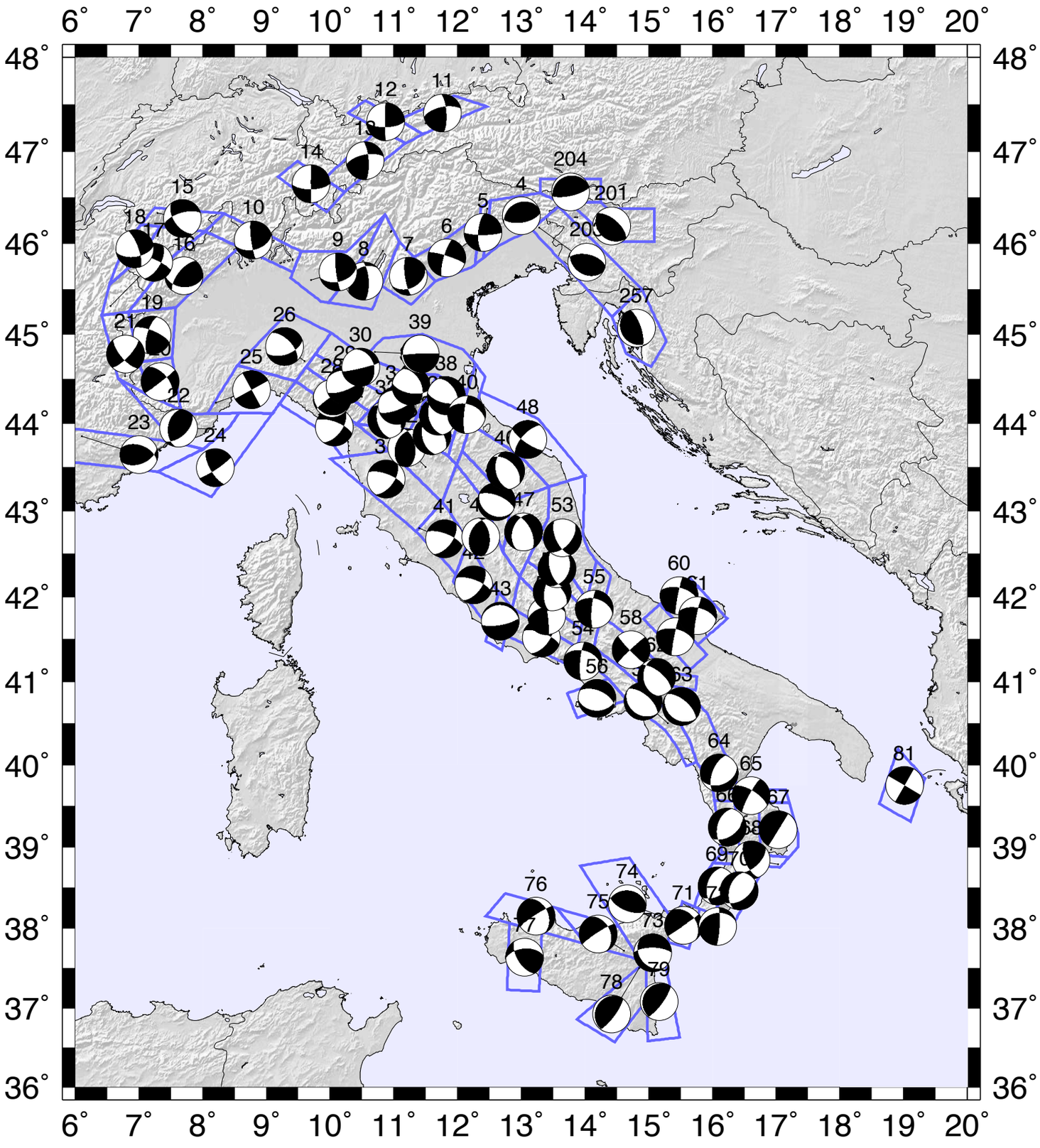
# Regional scale - Smoothed magnitude



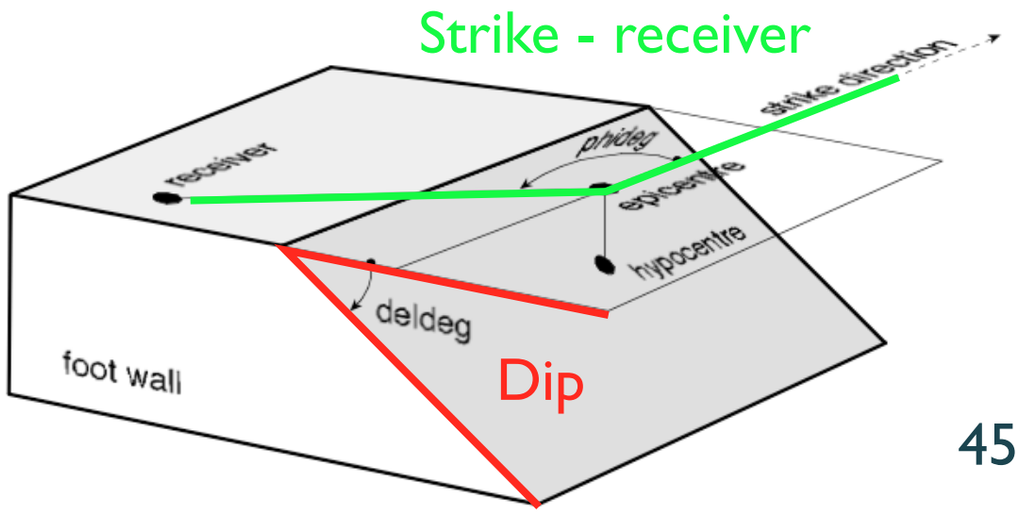
# Regional scale - Sources inside SZ

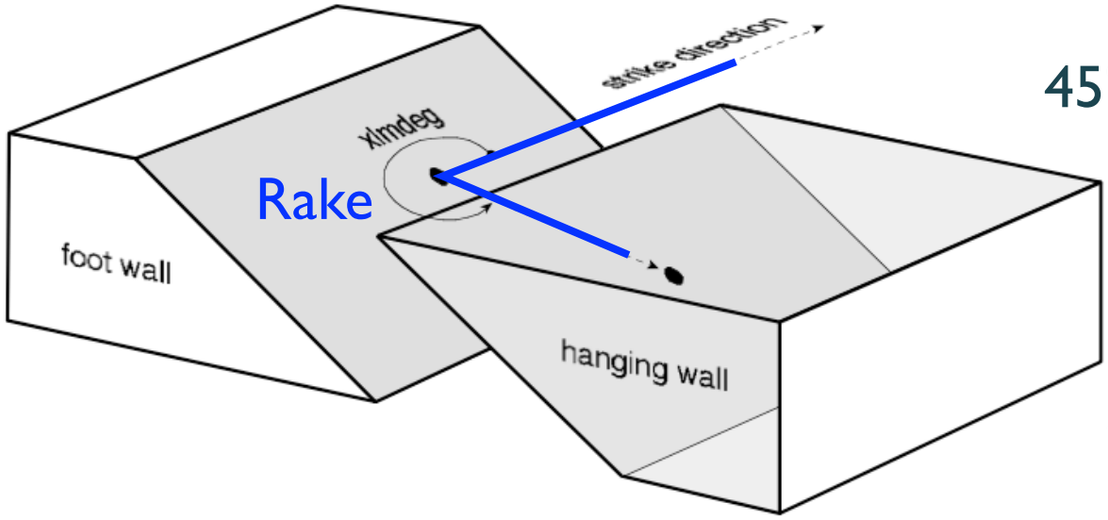


# Regional scale - Sources inside SZ

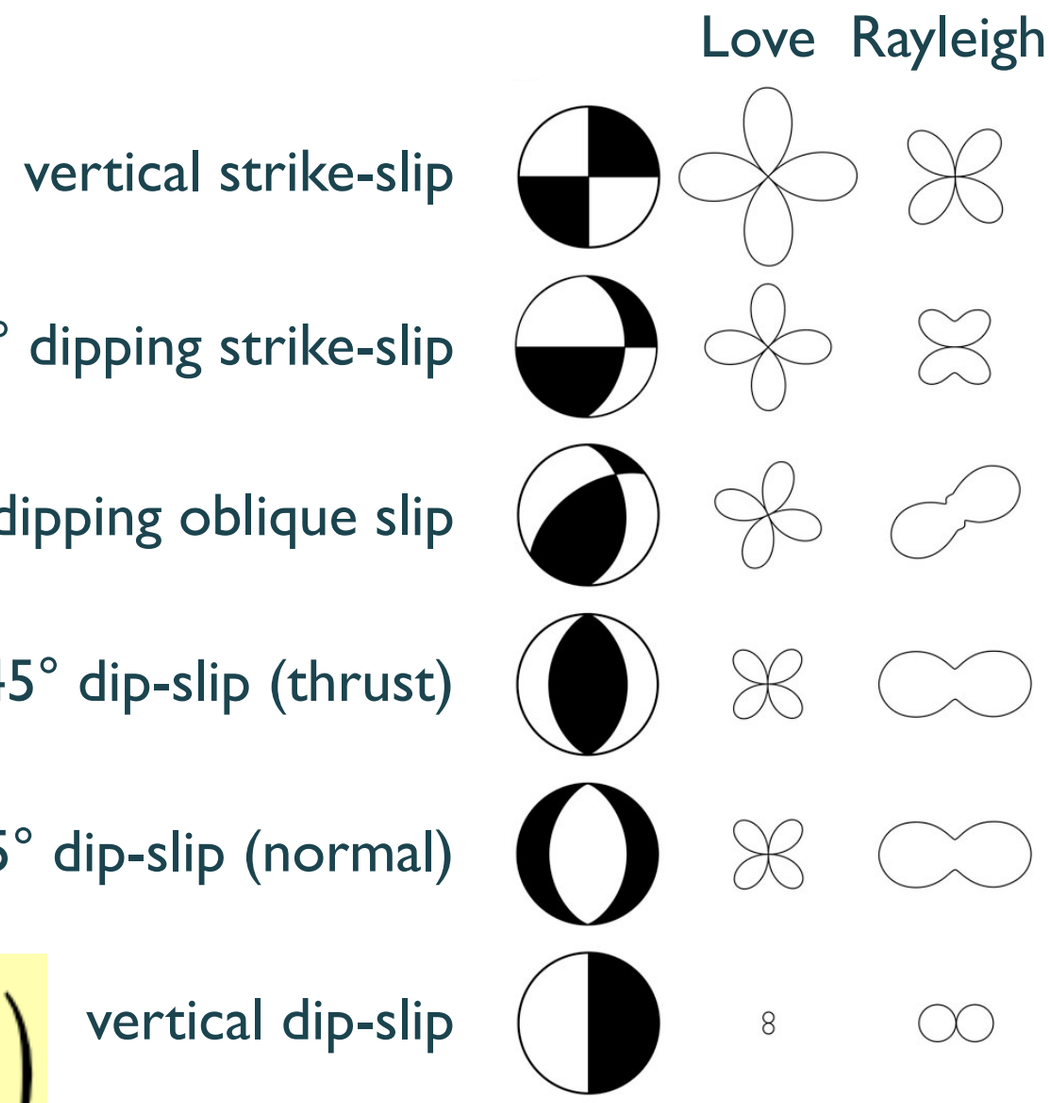


# Source definition - Radiation pattern



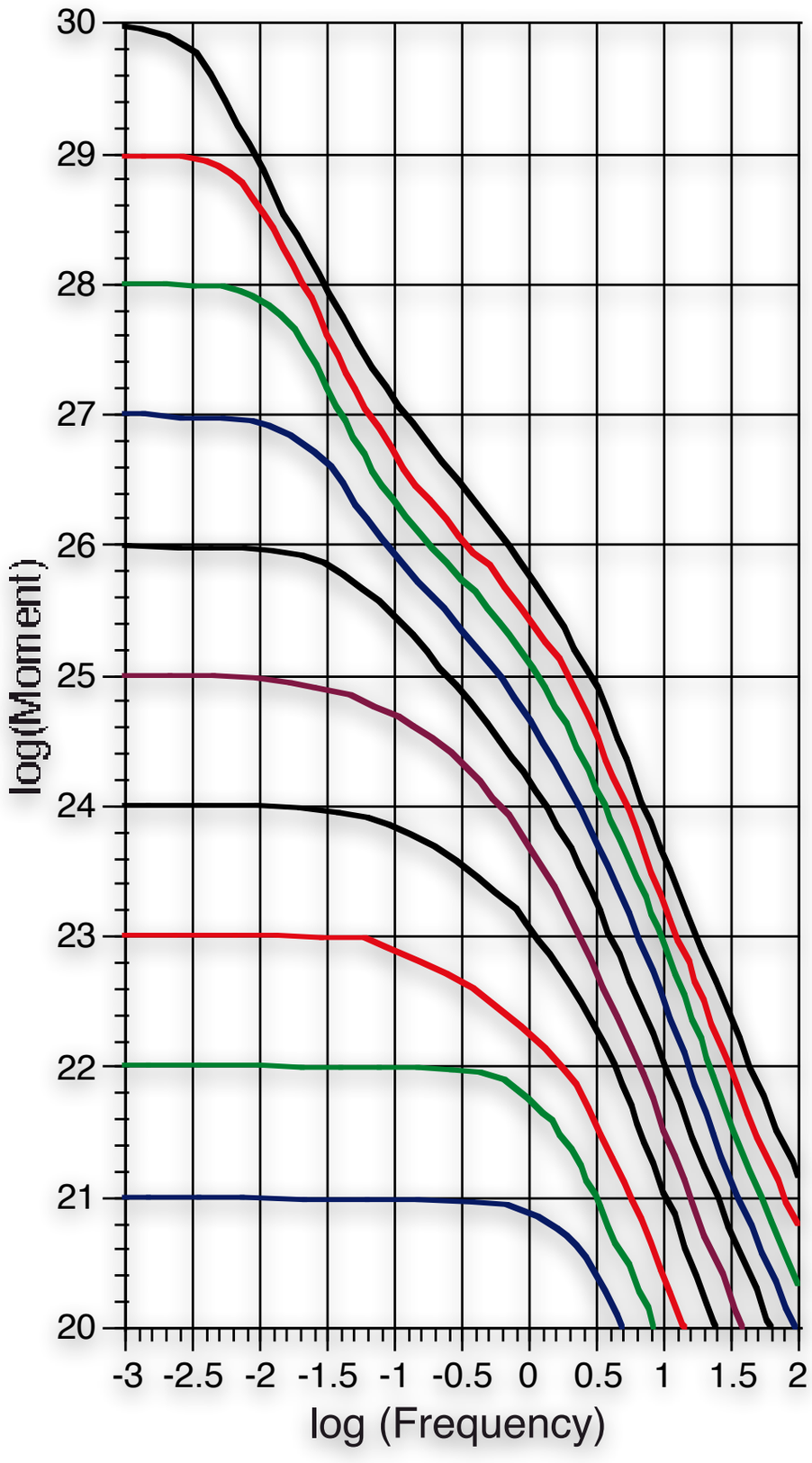




$$\left(\chi_m^L(h_s,\omega)\right) \qquad \left(\chi_m^R(h_s,\omega)\right)$$



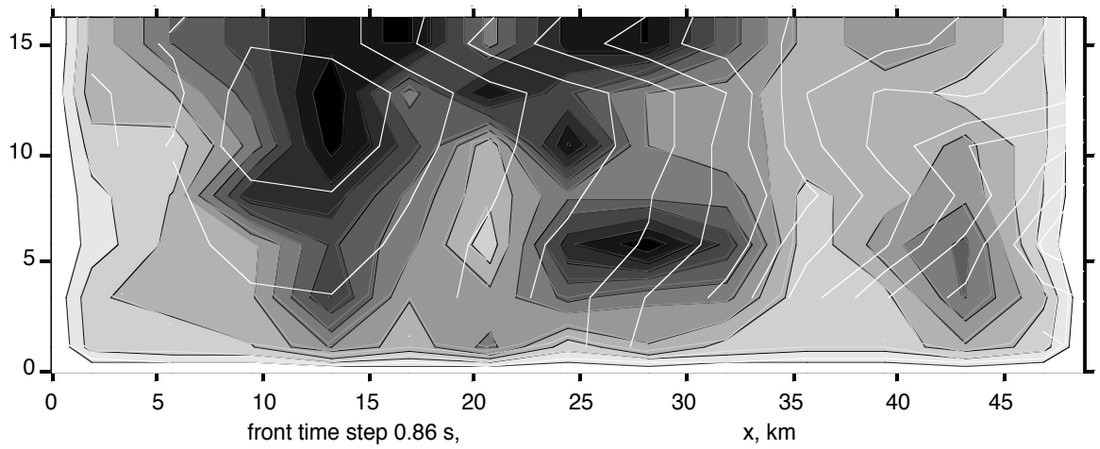
# Source definition - Scaled point source

- The moment-magnitude relation by Kanamori (1977) is used
- At first synthetic seismograms are computed for a unitary scalar seismic moment (1 dyn cm)
- Then they are scaled for magnitude in the frequency domain according to the spectral law by Gusev (1983) as reported in Aki (1987)



# Source definition - Scaled point source

## Source kinematic model



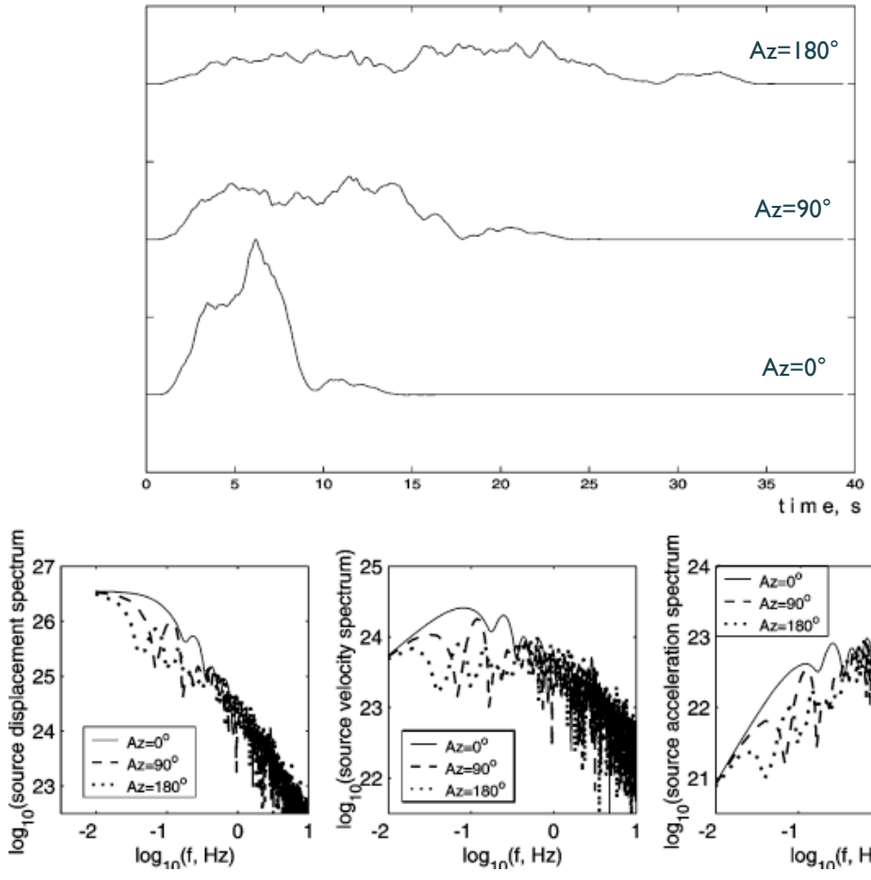

2-dimensional final slip distribution over a source rectangle, shown as a density plot (Mw=7.0).

Rupture front evolution was simulated kinematically from random rupture velocity field.

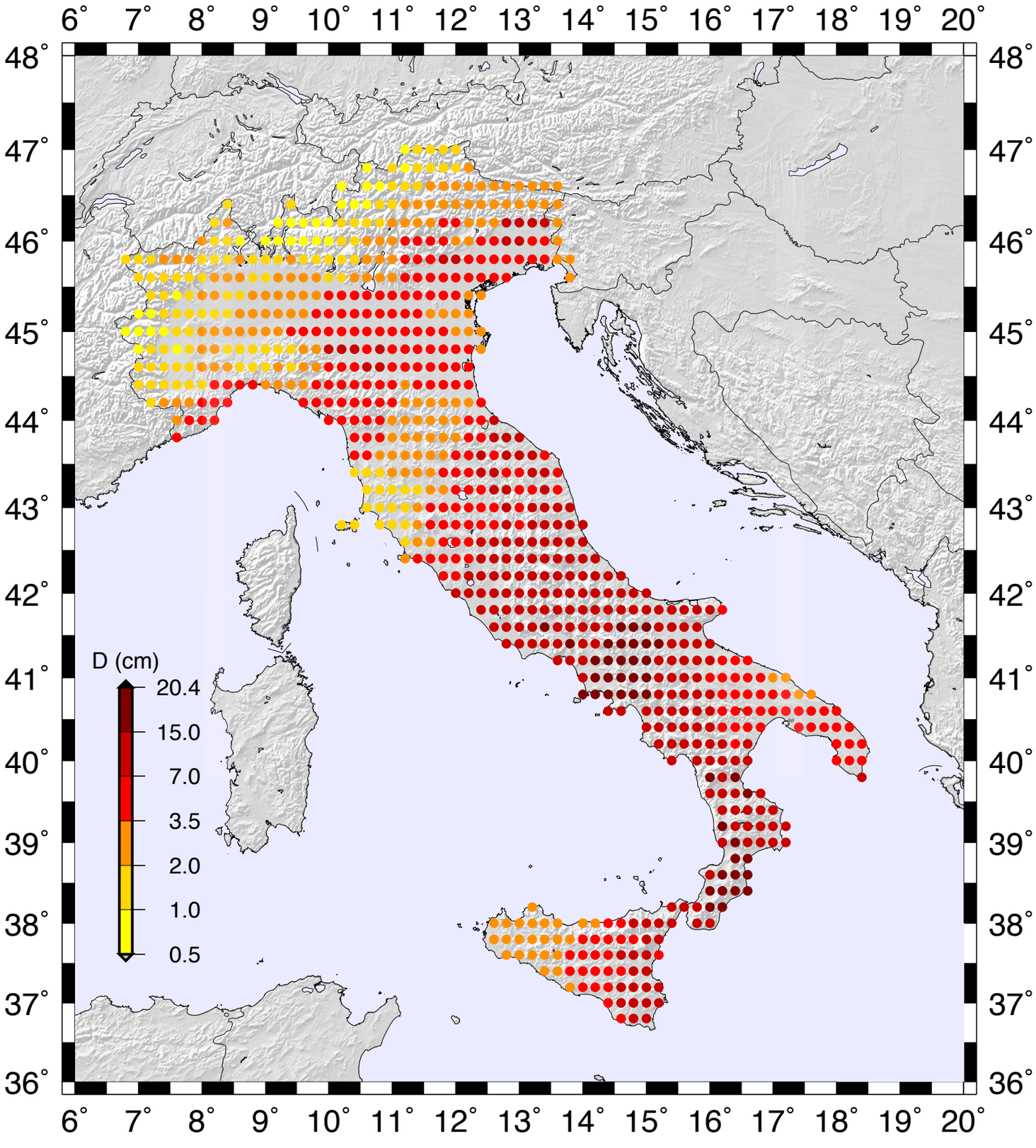
(Gusev, 2011)

Far-field source time histories and their spectra.

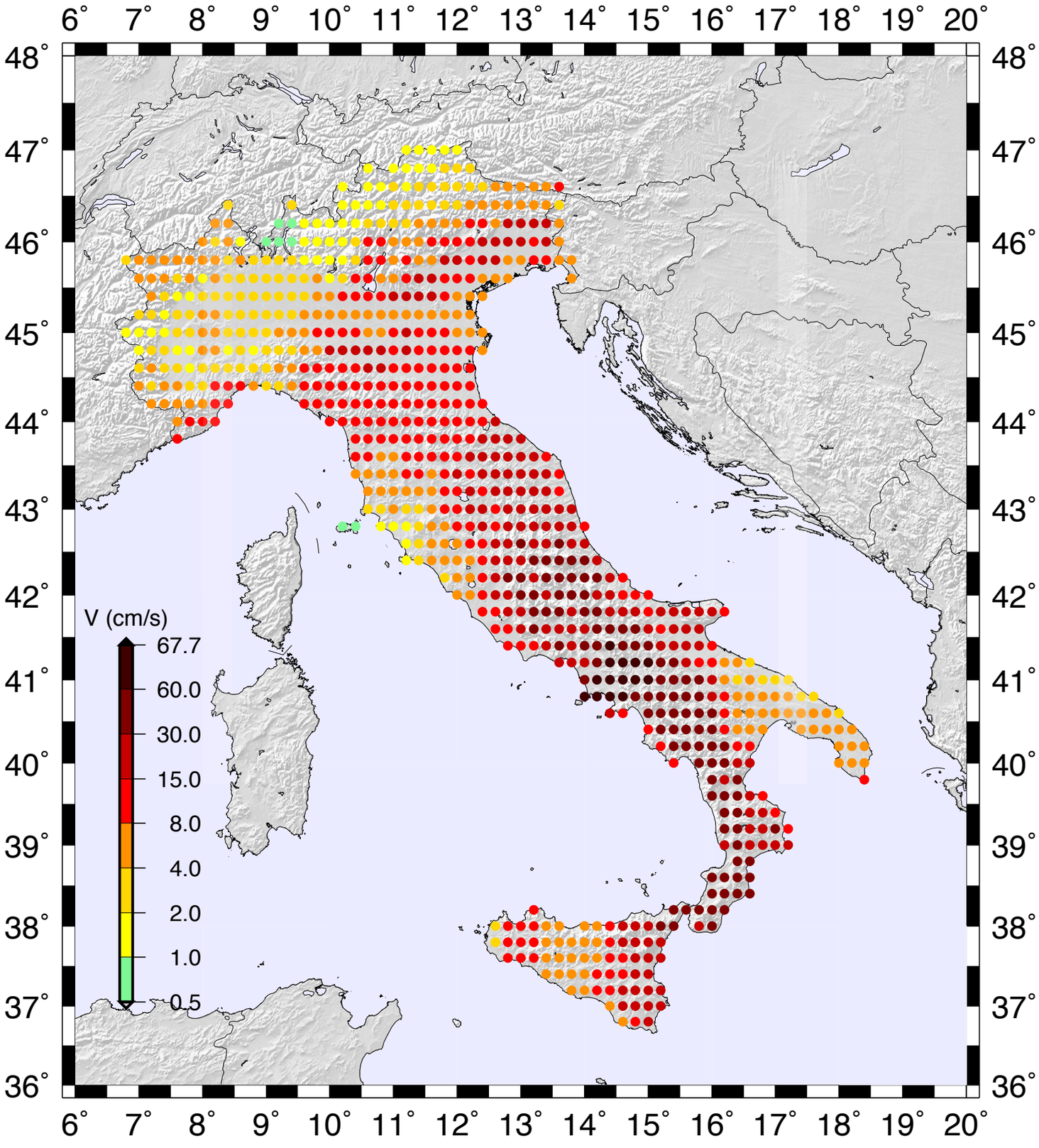
"Displacement" far-field functions (arbitrary scale) for the simulated case of mostly unilateral rupture propagation



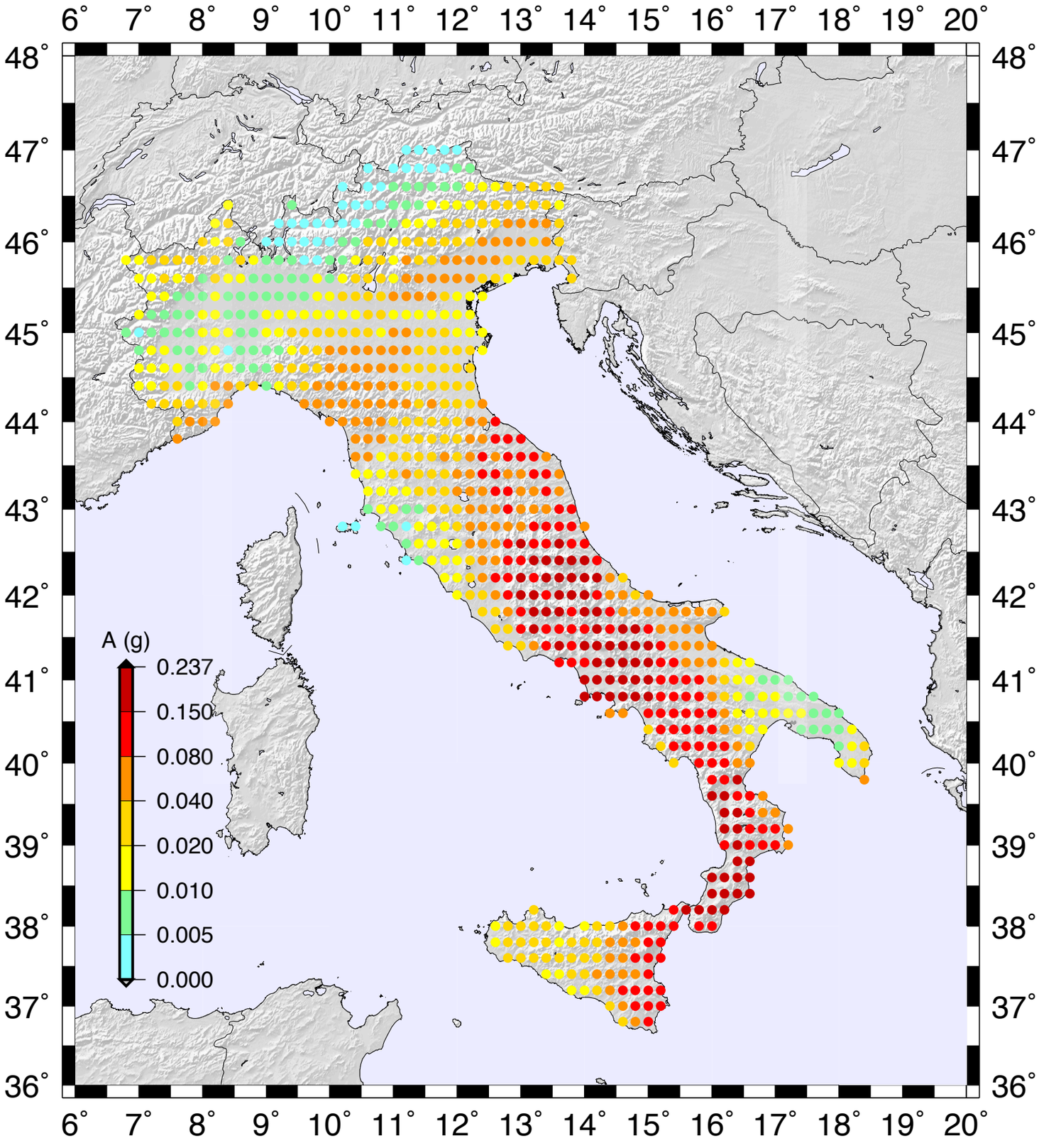
# Example computation - Ground shaking



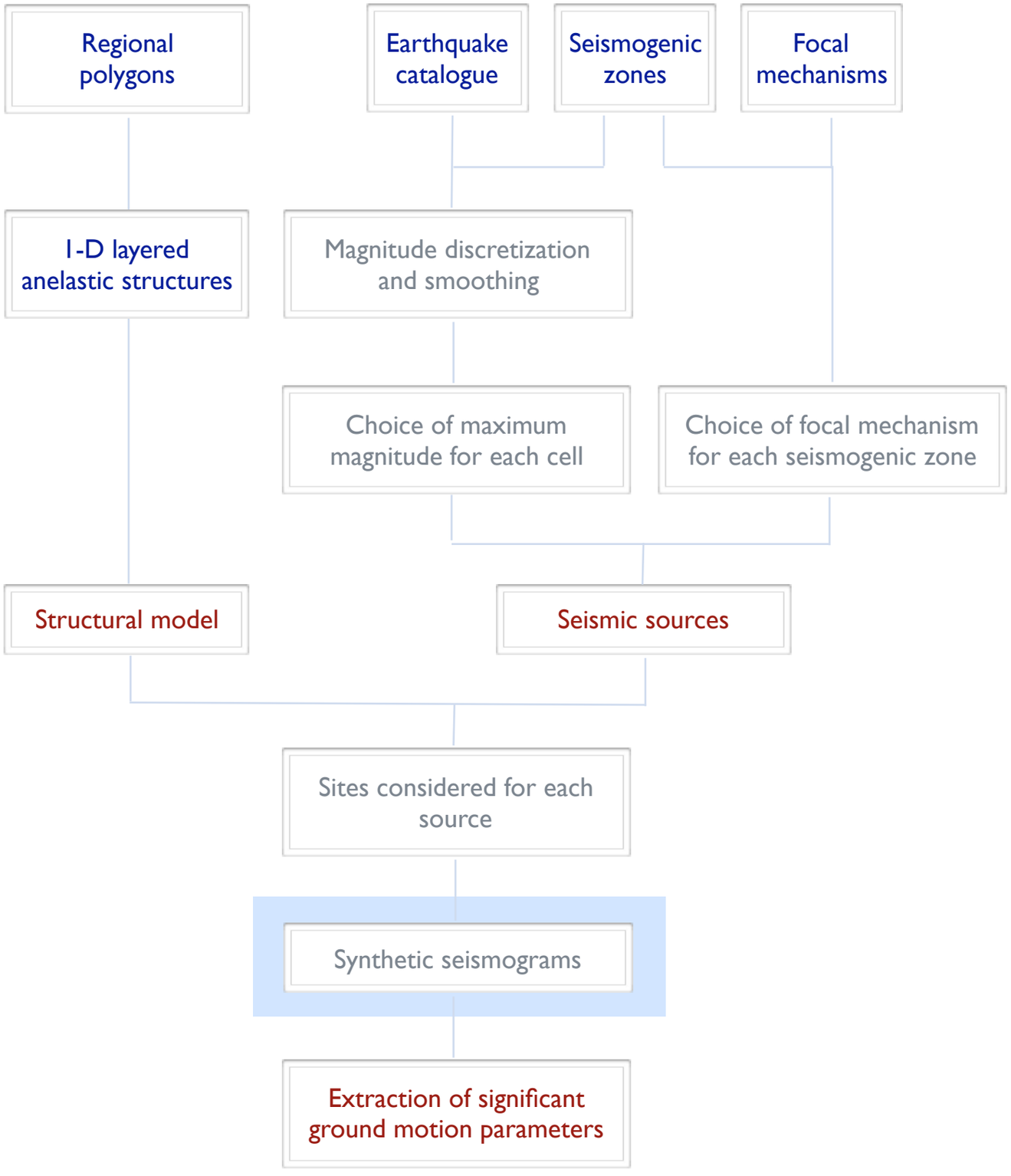
# Example computation - Ground shaking

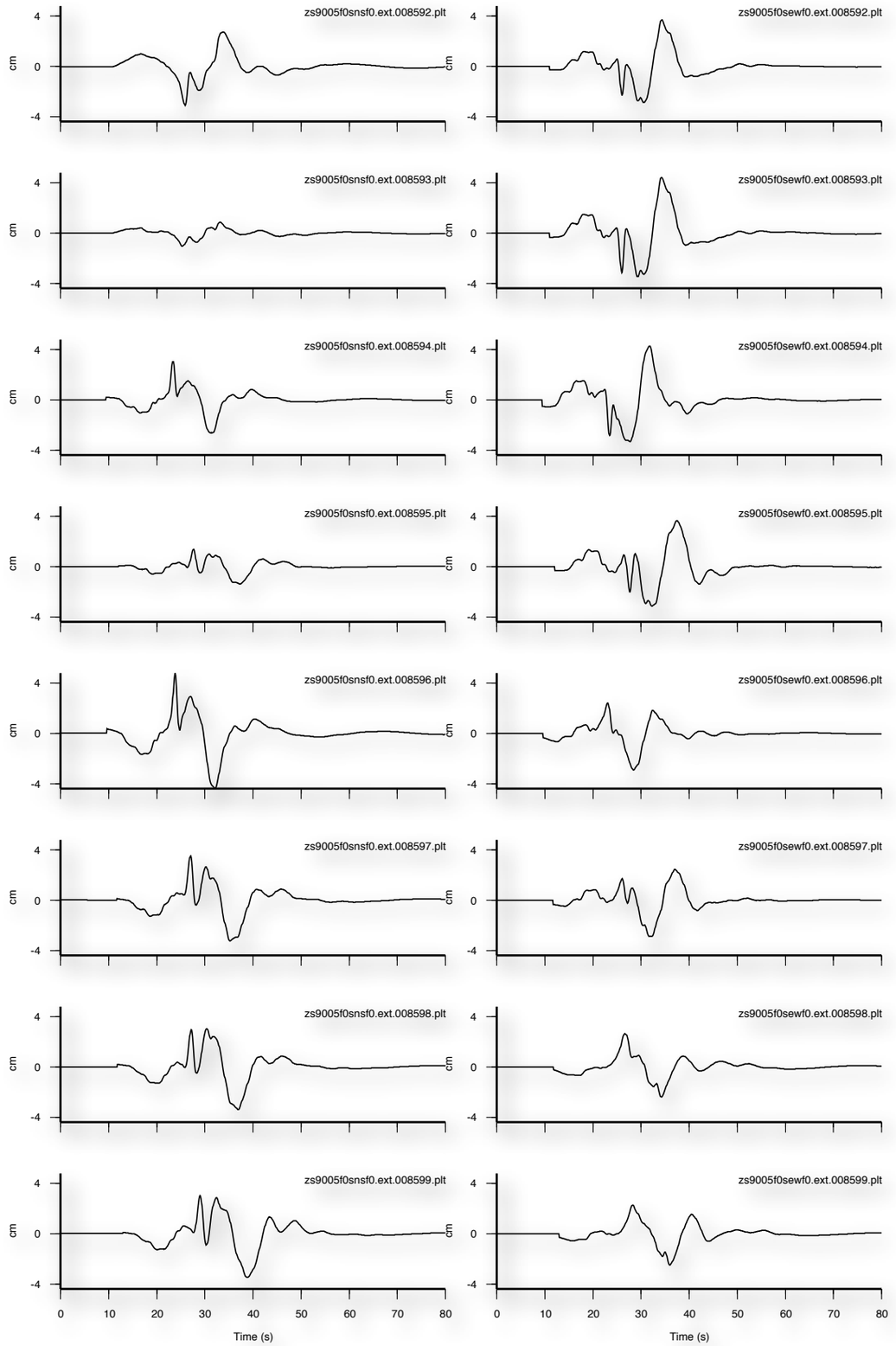


# Example computation - Ground shaking

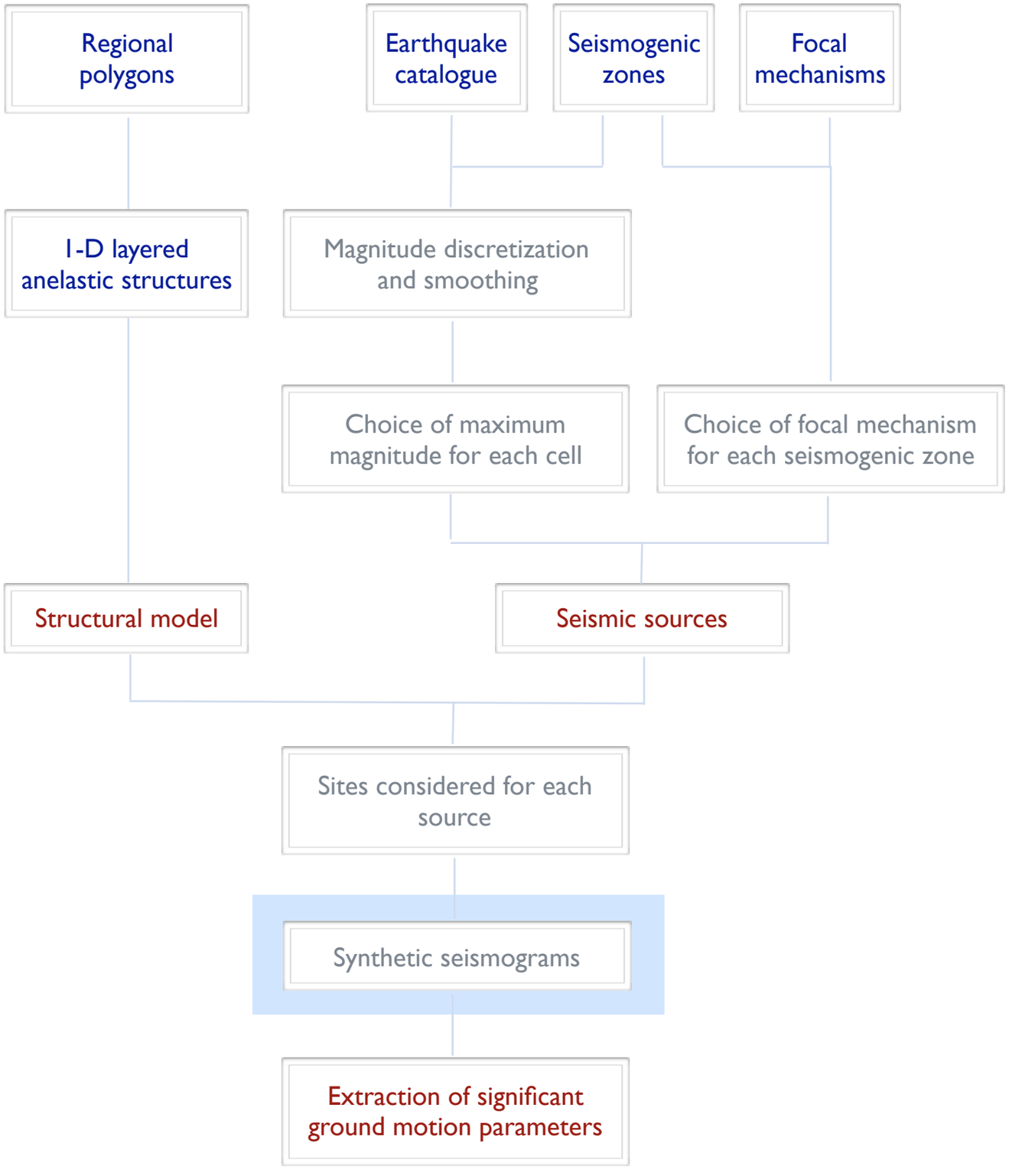


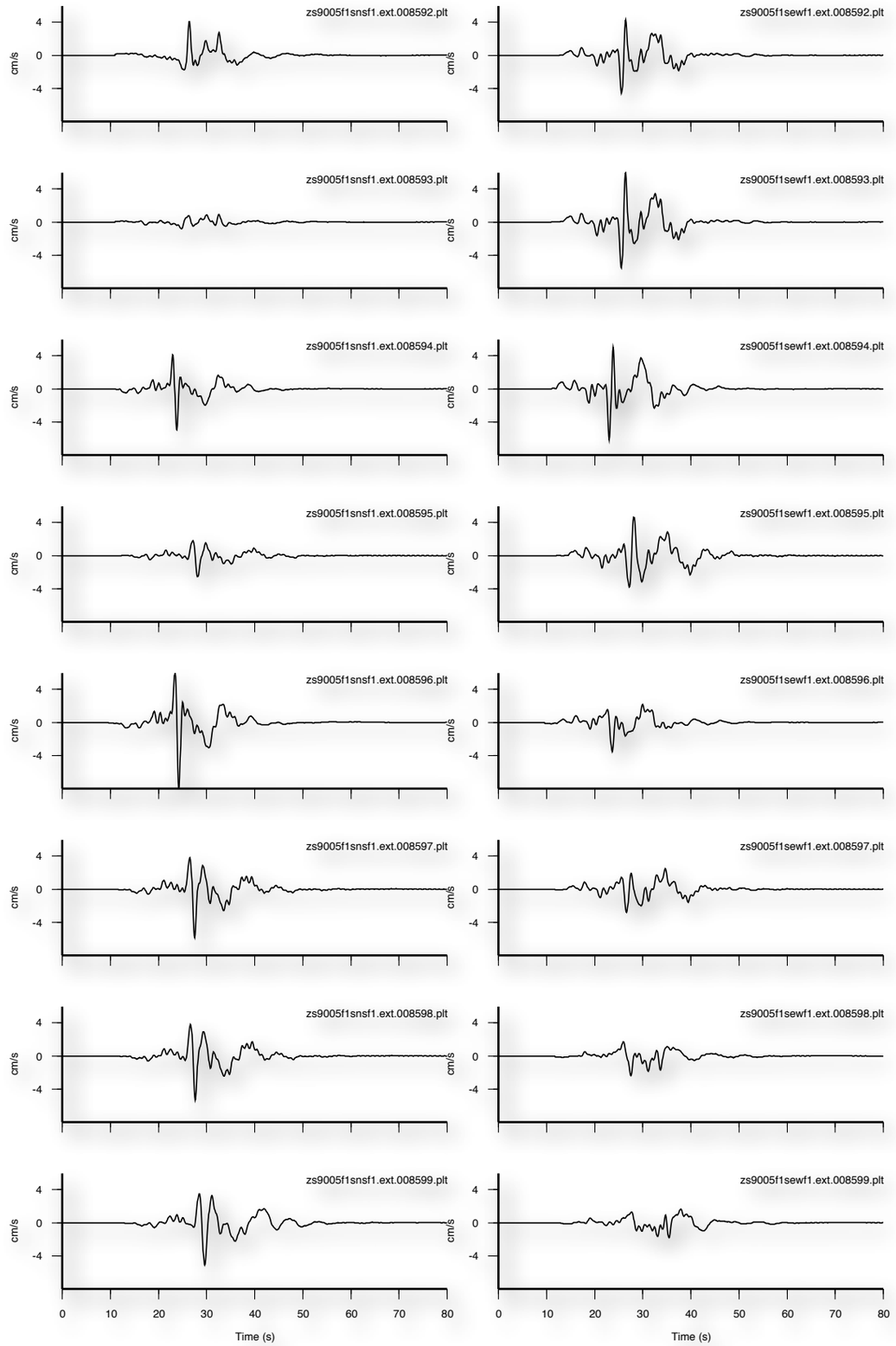
# Regional Scale - Displacement



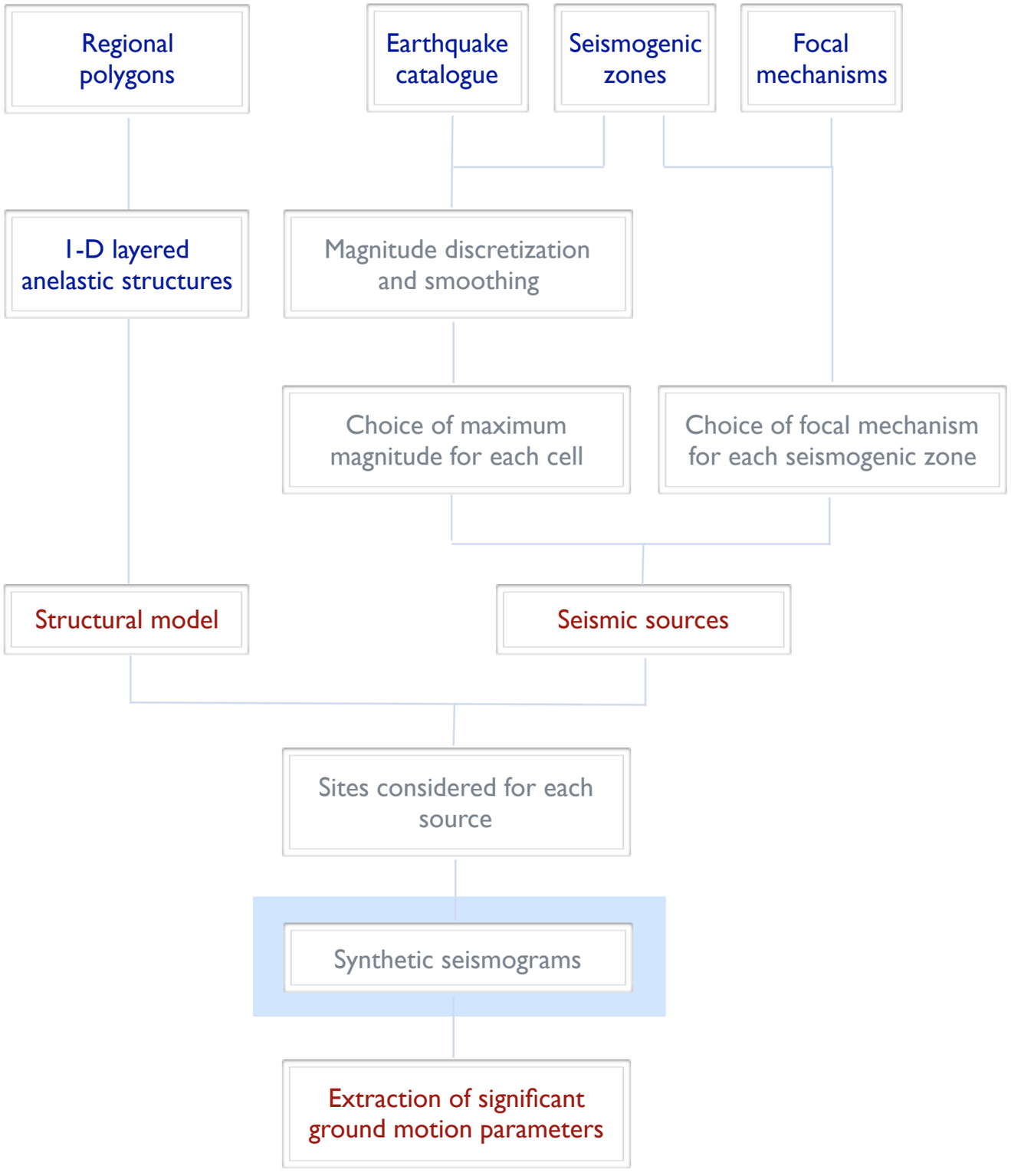



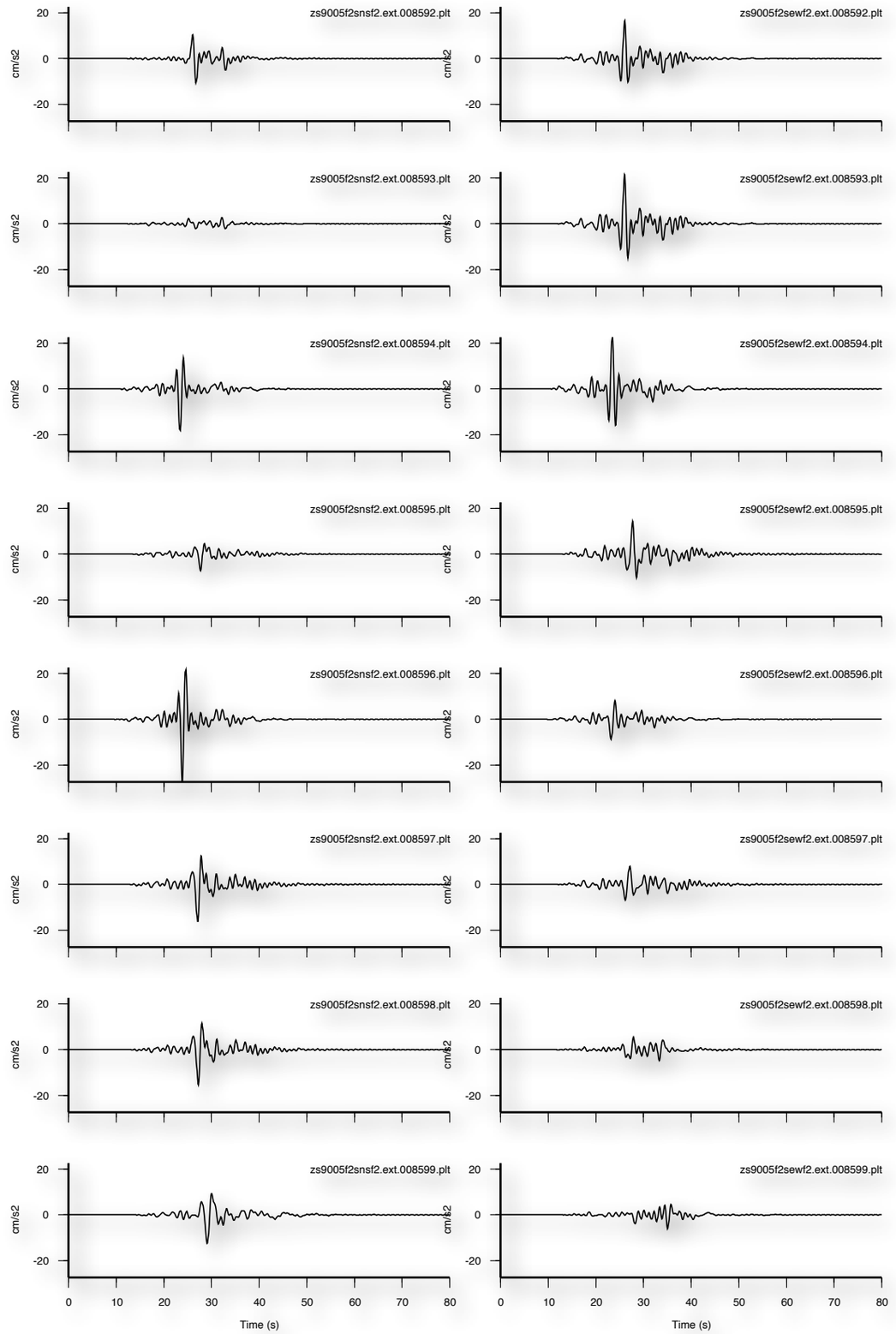
# Regional Scale - Velocity



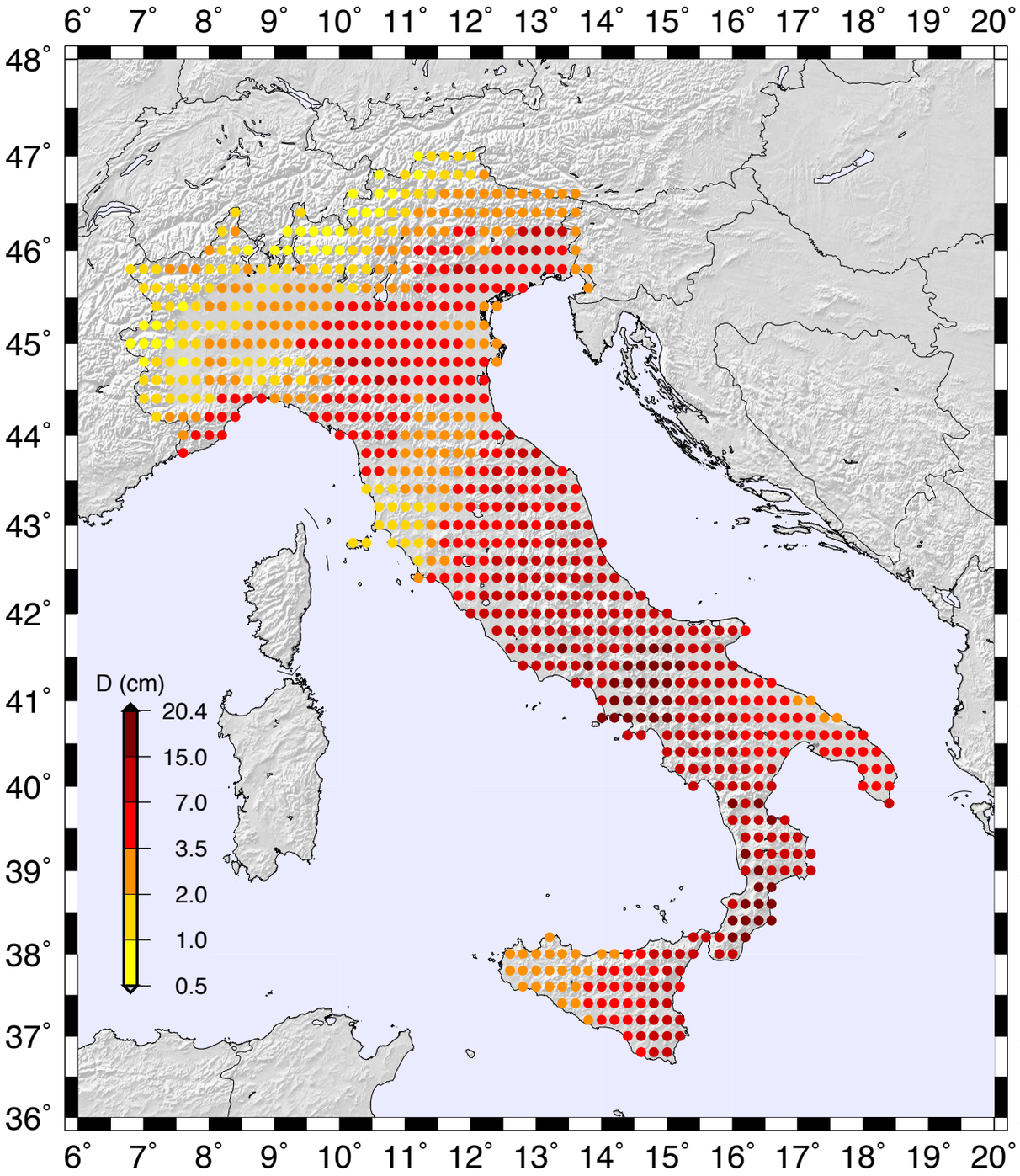
# Regional Scale - Acceleration



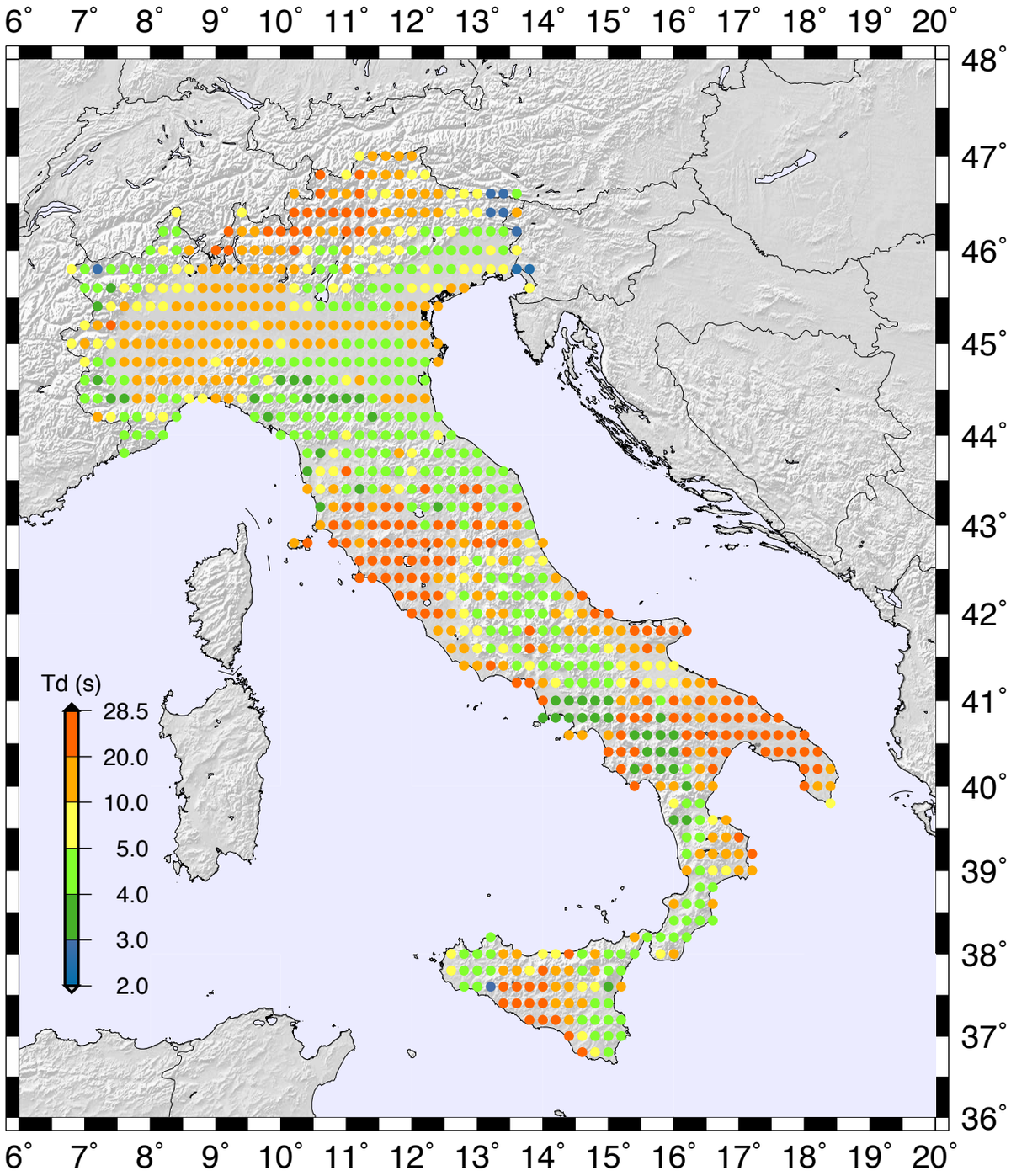



# Displacement

## Amplitude of Peaks from Time Series (1Hz)

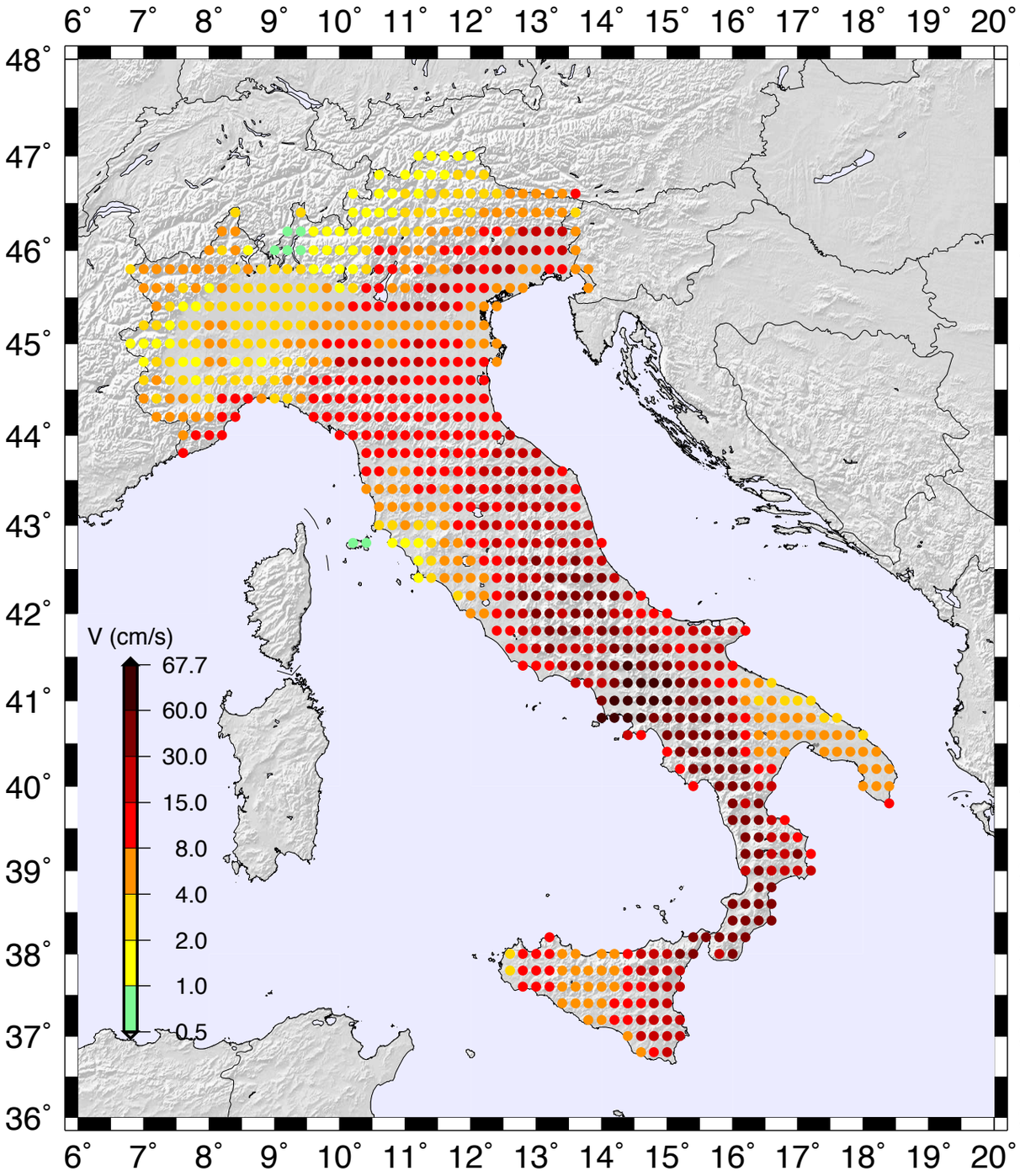



## T of Peaks from Fourier Spectra

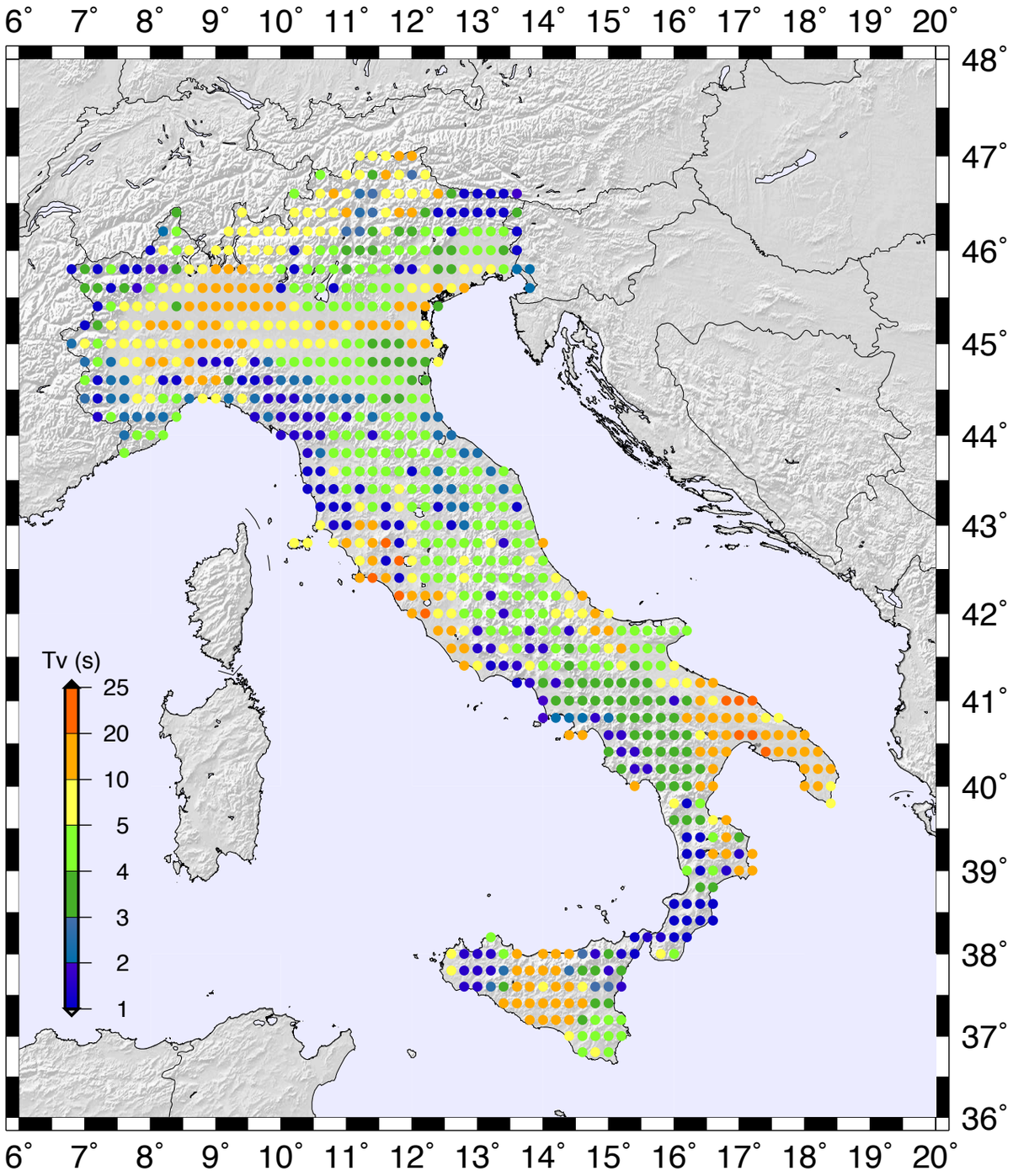


# Velocity

## Amplitude of Peaks from Time Series (1Hz)

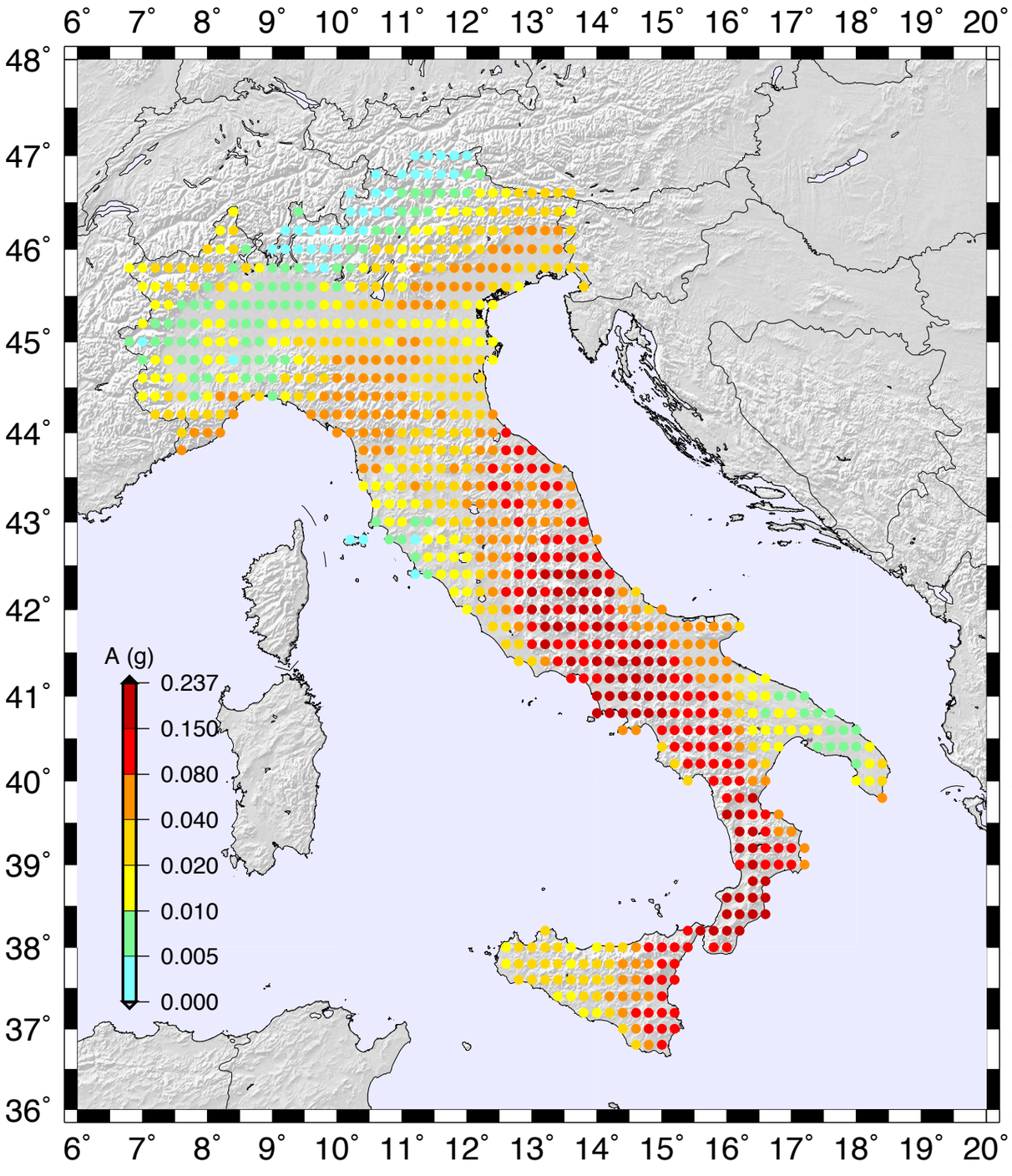



## T of Peaks from Fourier Spectra

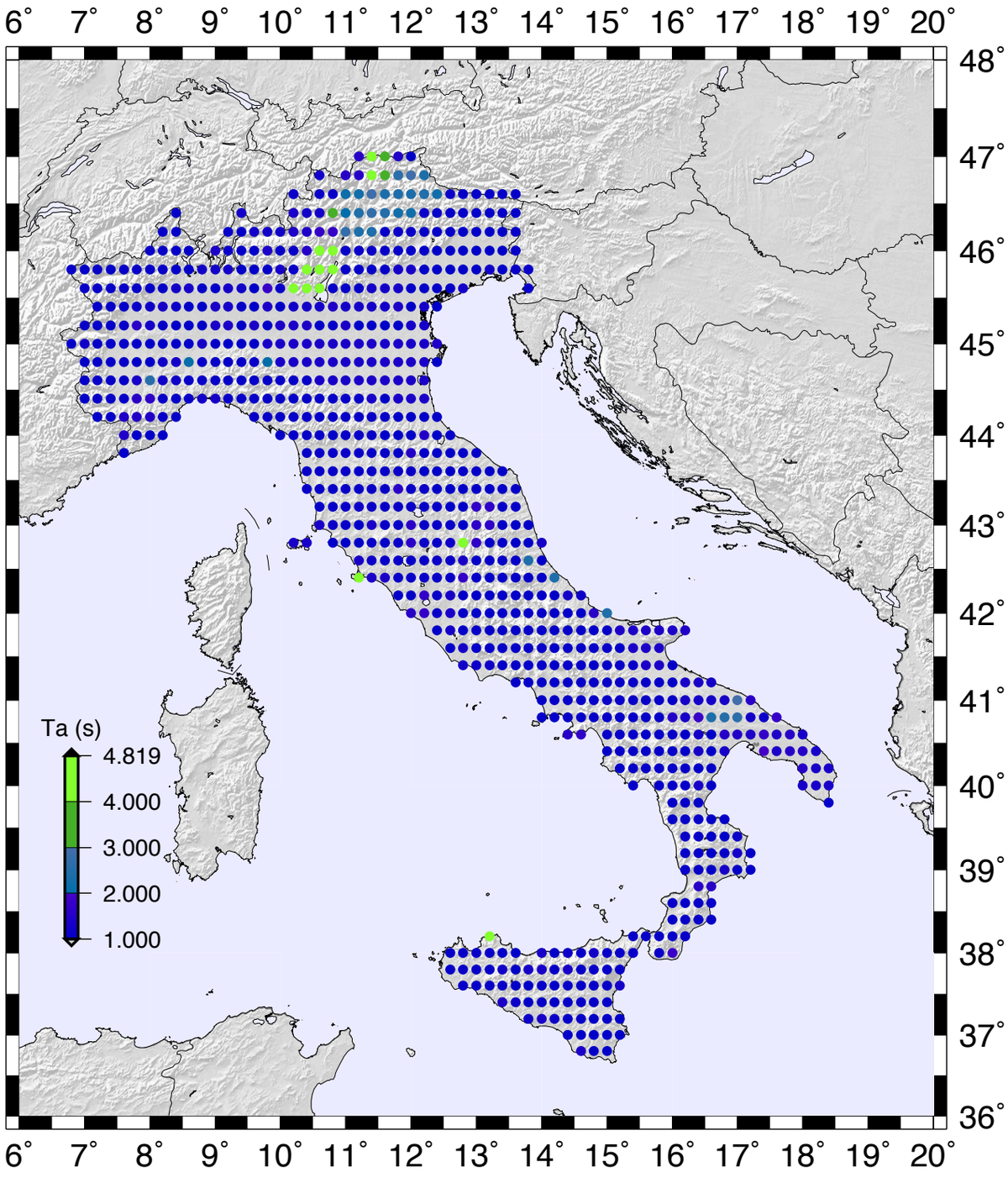


# Acceleration

## Amplitude of Peaks from Time Series (1Hz)

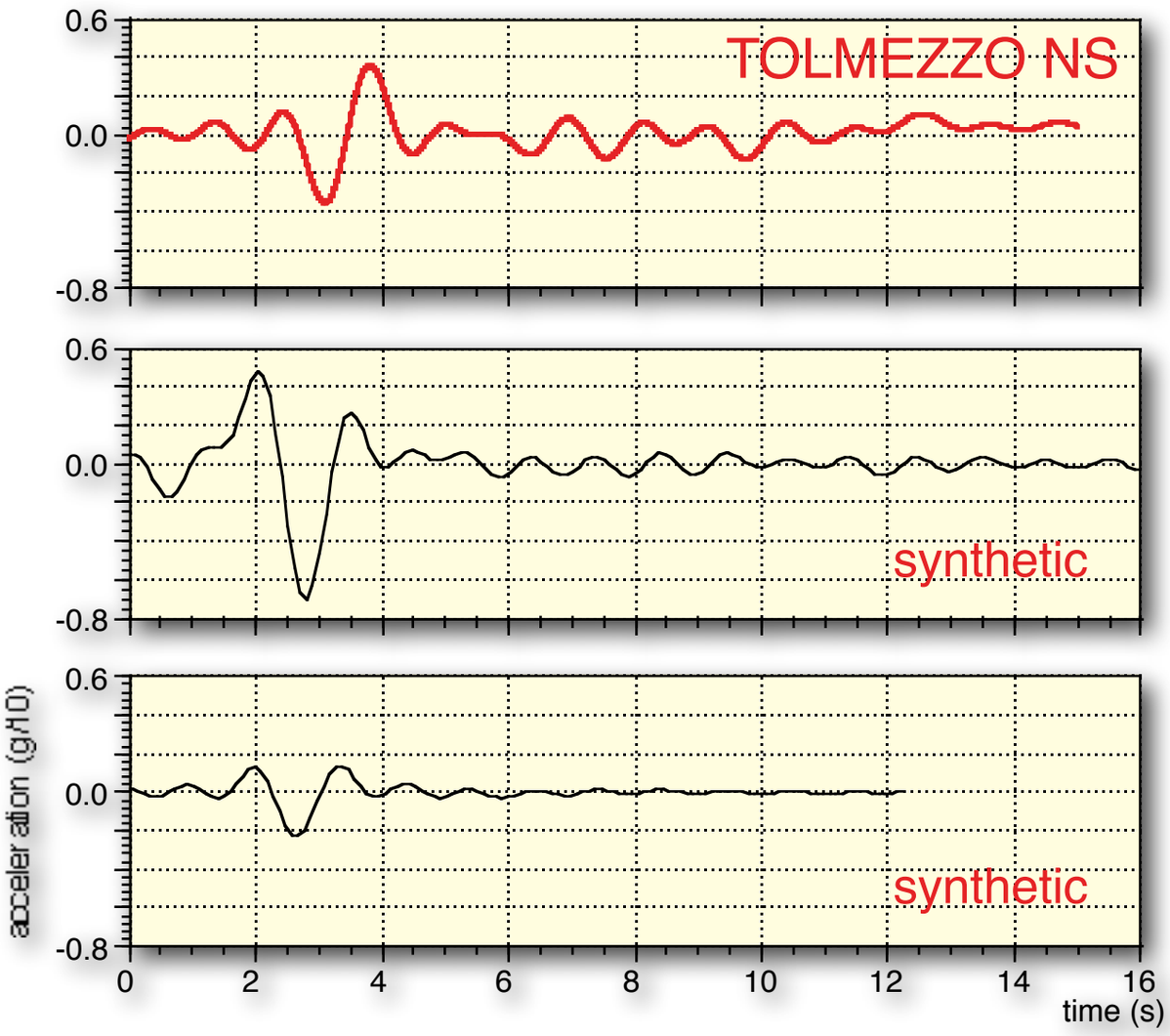



## T of Peaks from Fourier Spectra



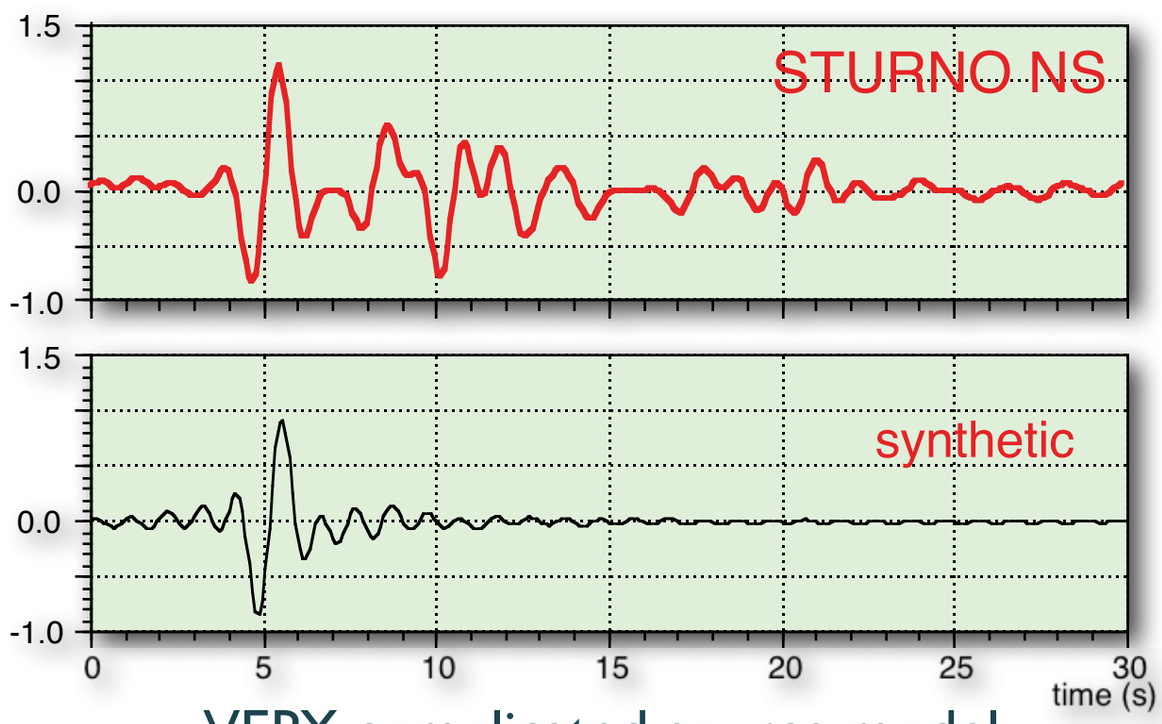
# Regional Scale - Check (1 Hz cutoff)

## Friuli, 6 May 1976 (North-Eastern Italy)




Comparison with two grid nodes close to the Tolmezzo station

## Irpinia, 23 October 1980 (Southern Italy)

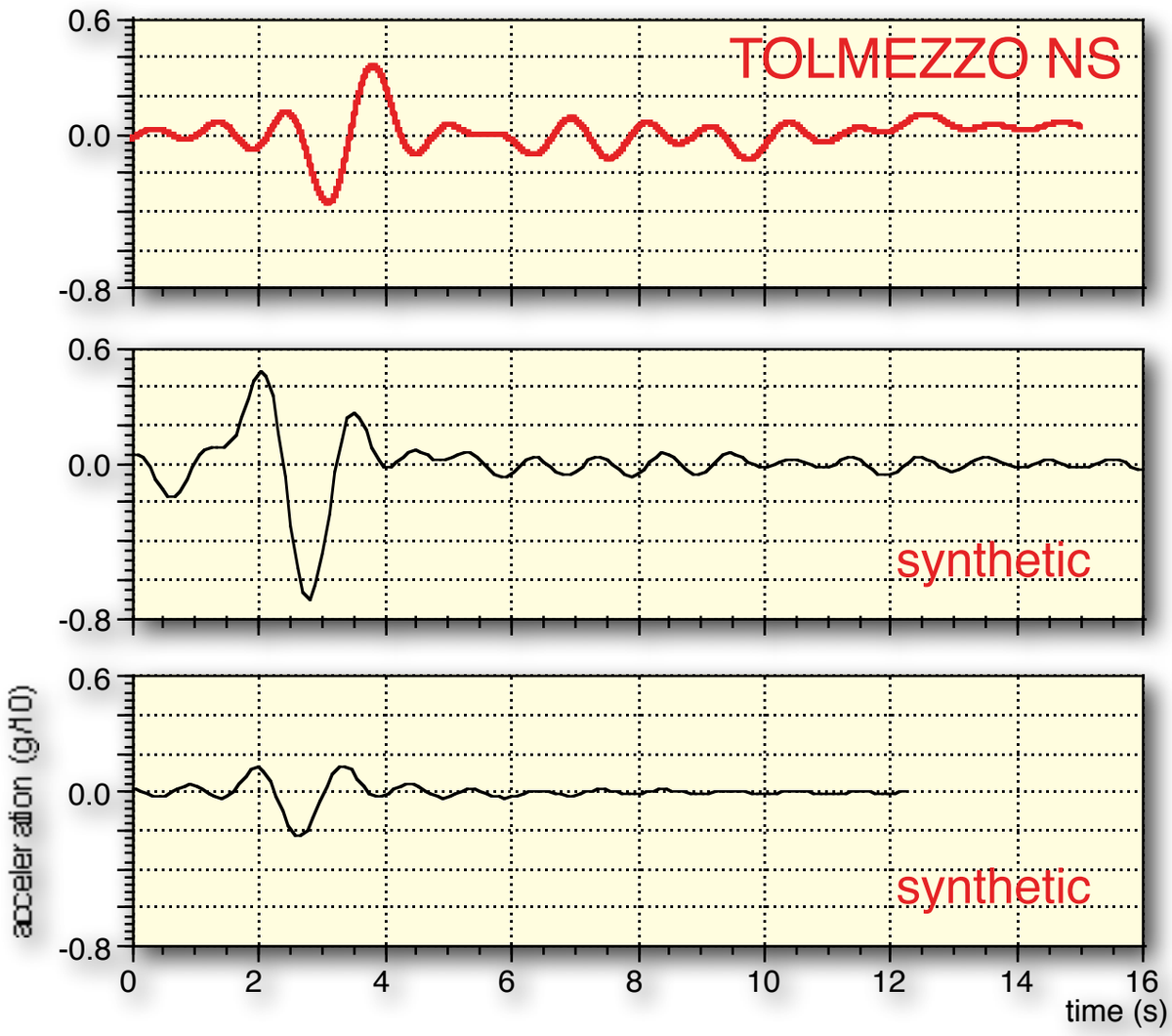



VERY complicated source model

Point-source inadequate to reproduce duration, but peak value is OK

# Regional Scale - Check (1 Hz cutoff)

## Friuli, 6 May 1976 (North-Eastern Italy)

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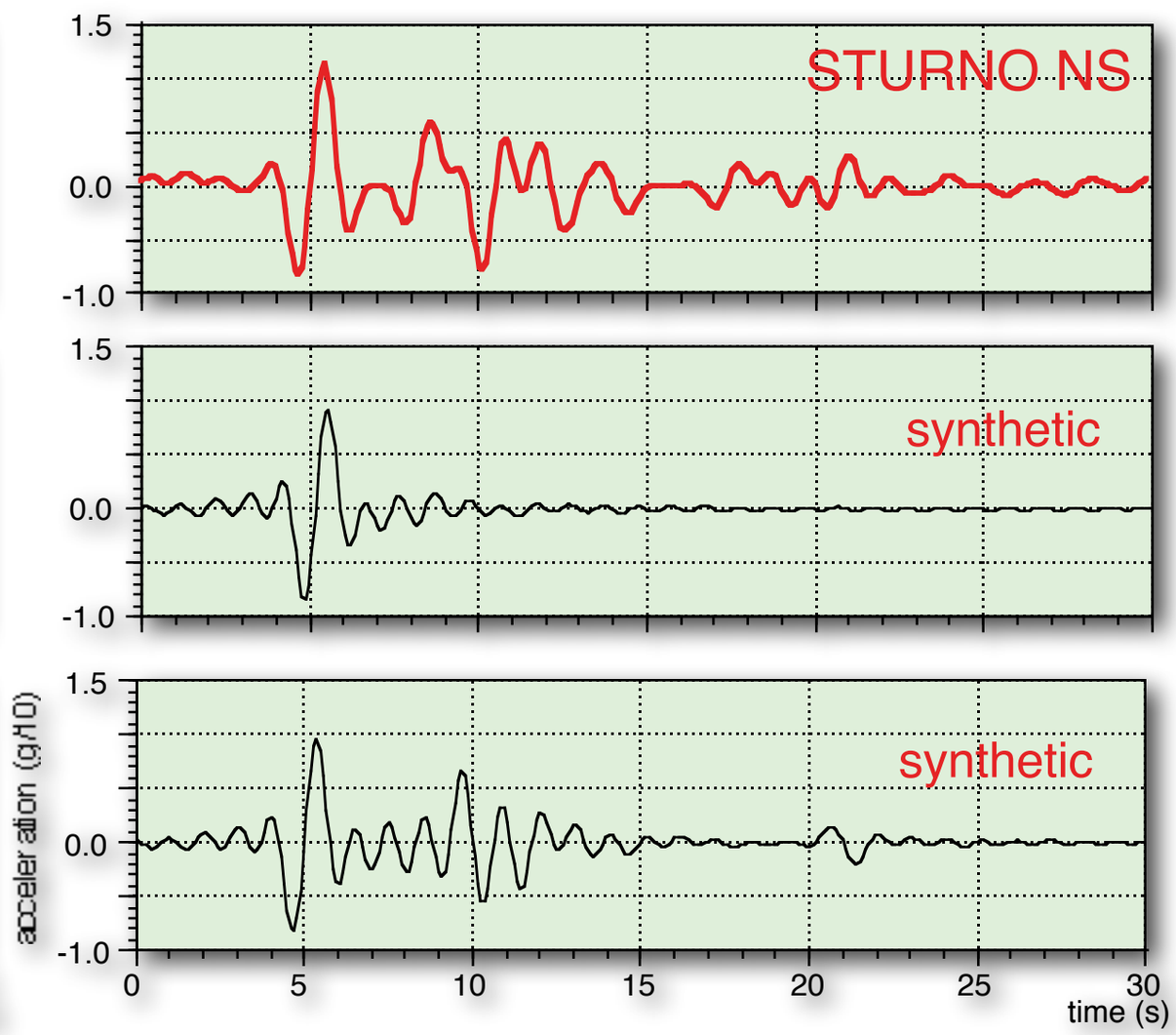
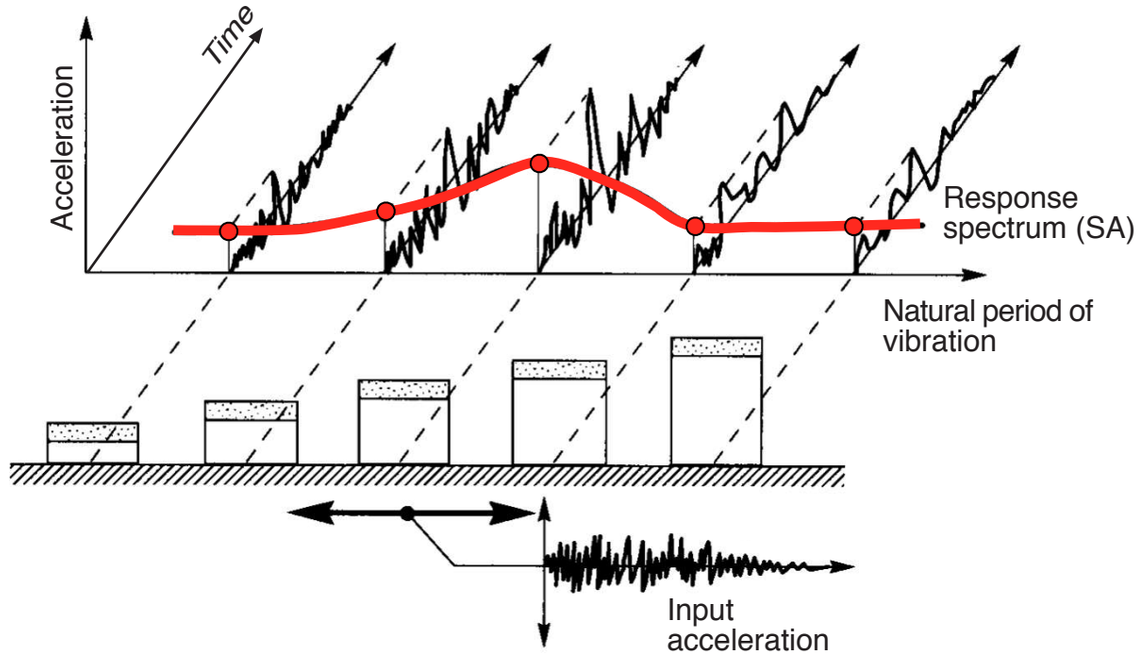



With a sequence of point sources the duration can be reproduced but this is deliberately neglected since rupturing process is not known a priori

# Design Ground Acceleration (DGA)

- To obtain an estimate of PGA, overcoming the 1 Hz limitation chosen in the modelling, the shape of Design Spectra can be used

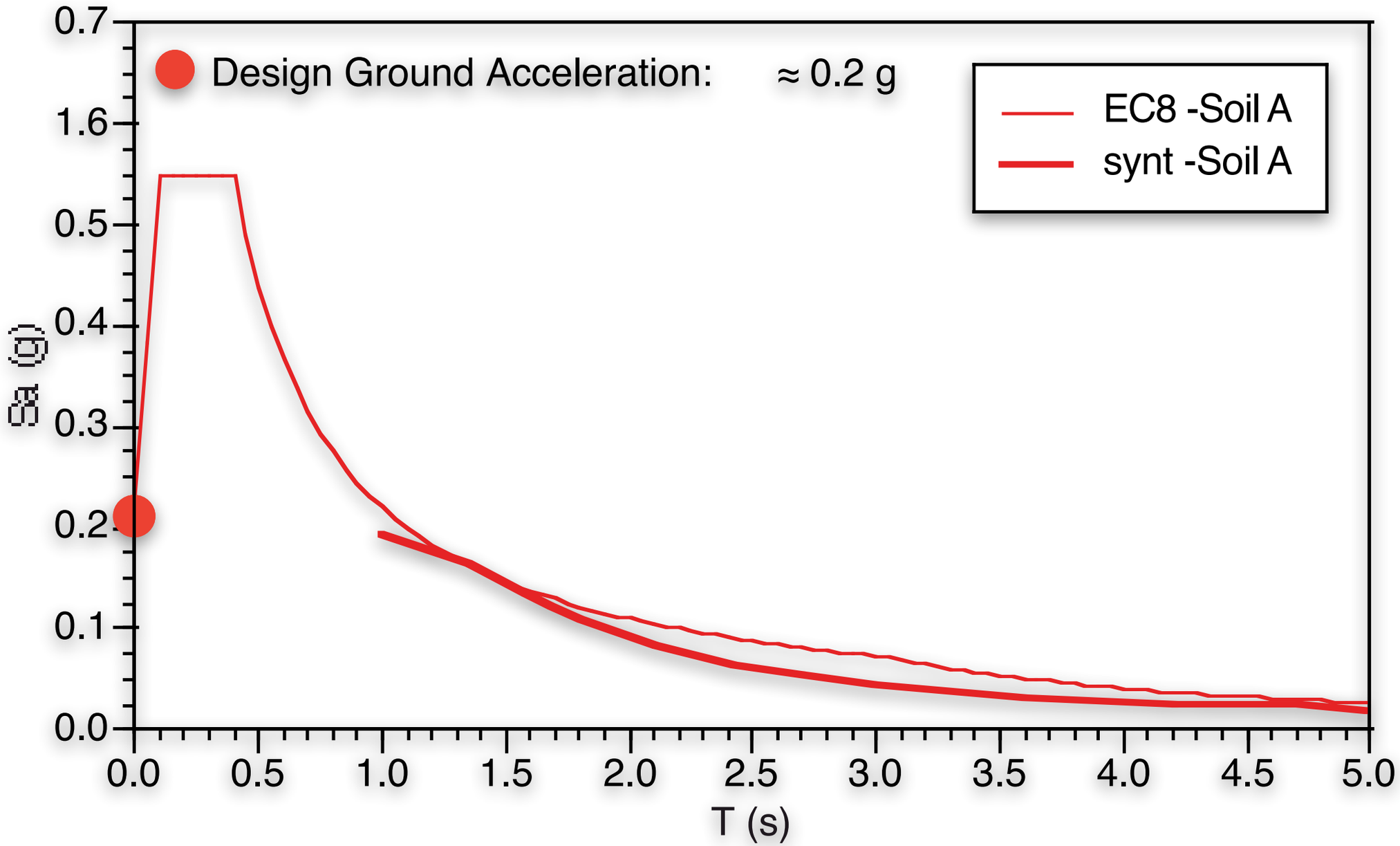
Response spectrum




- Rule of thumb for a rough estimate of the resonance period: T=1 s every 10 floors, but it strongly depends on the building characteristics (type of construction, geometry etc)

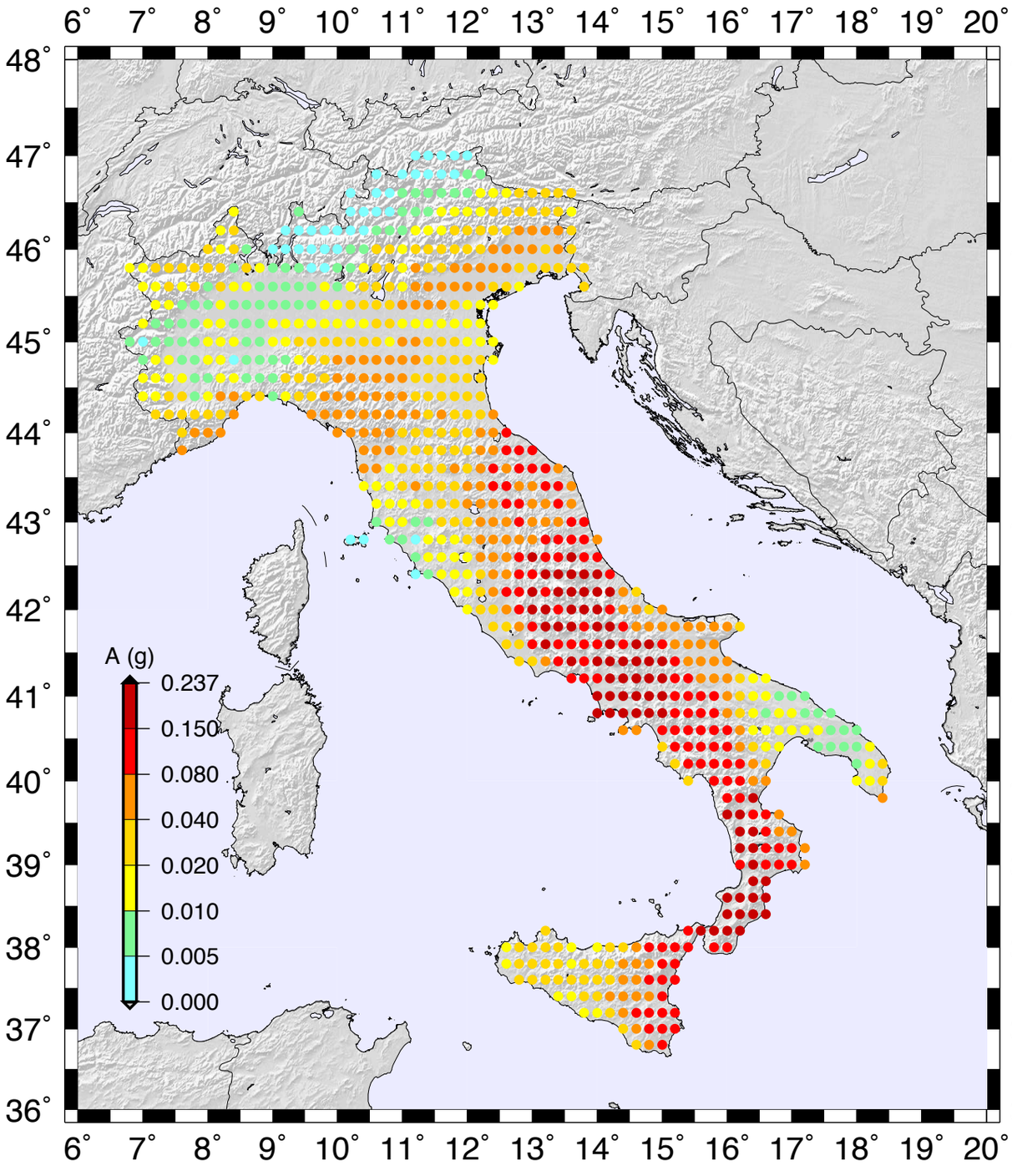
# Design Ground Acceleration (DGA)

- To obtain an estimate of PGA, overcoming the 1 Hz limitation chosen in the modelling, the shape of Design Spectra can be used

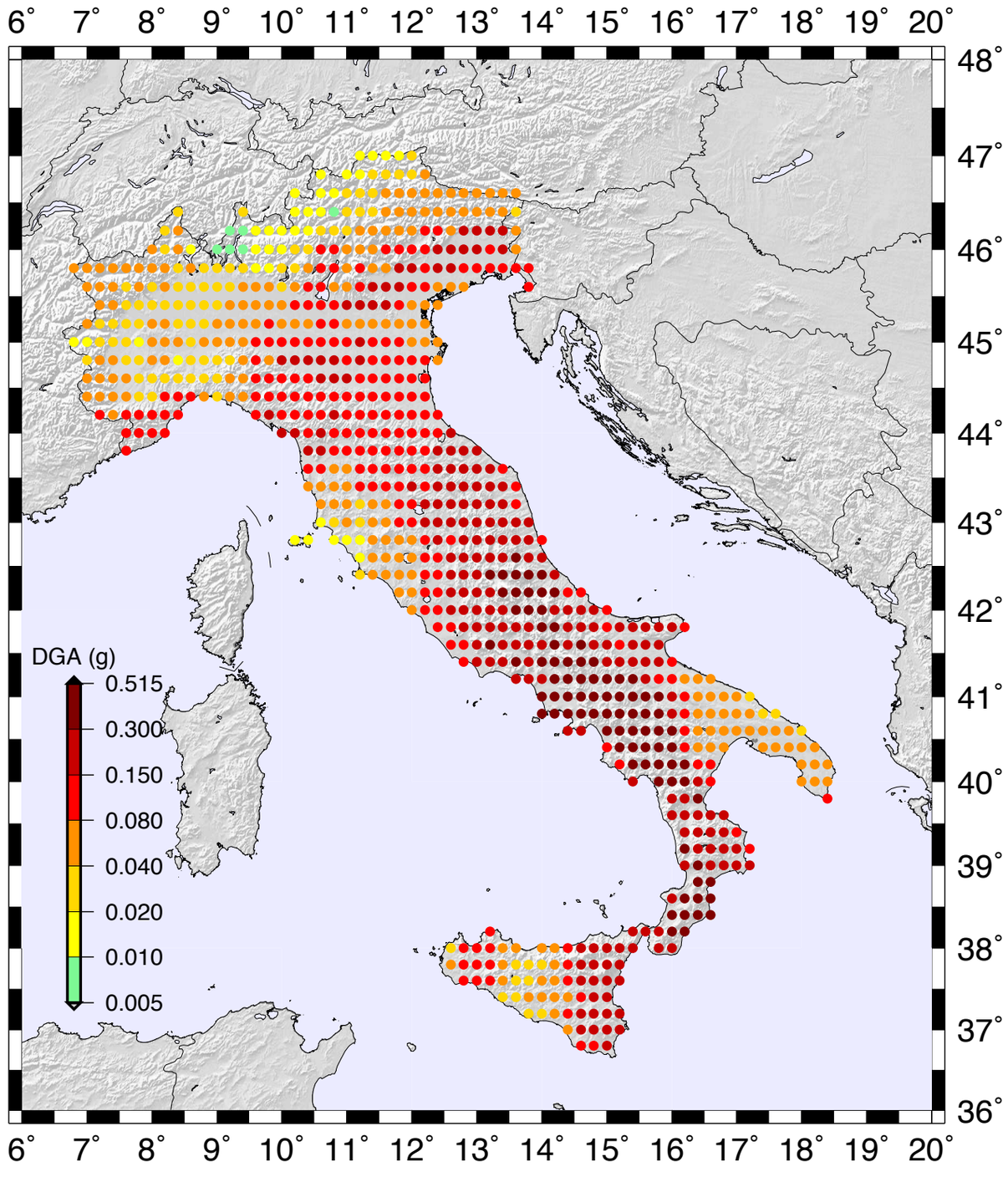


# Acceleration

## Amplitude of Peaks from Time Series (1Hz)

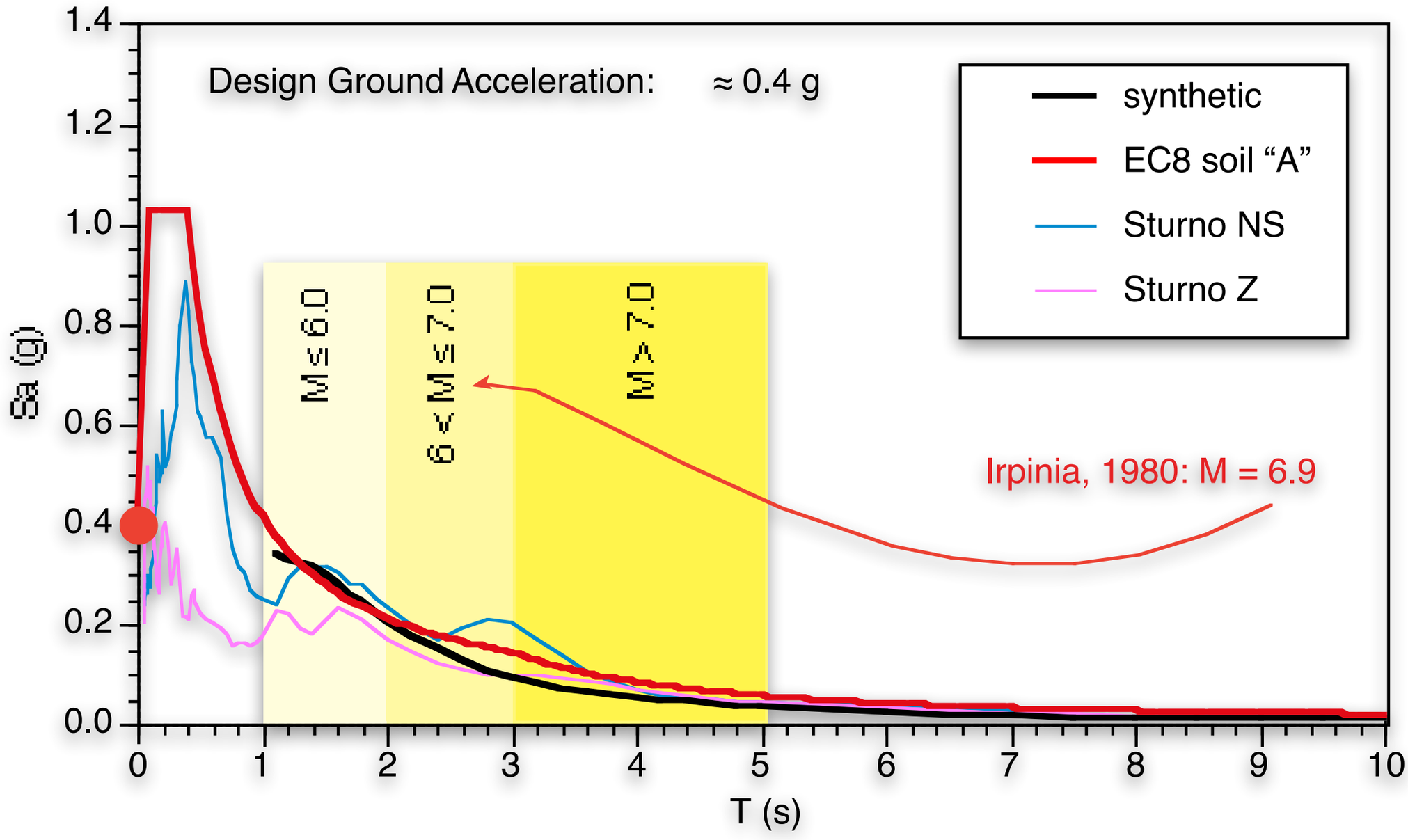



## DGA Extrapolated by Means of Design Spectrum



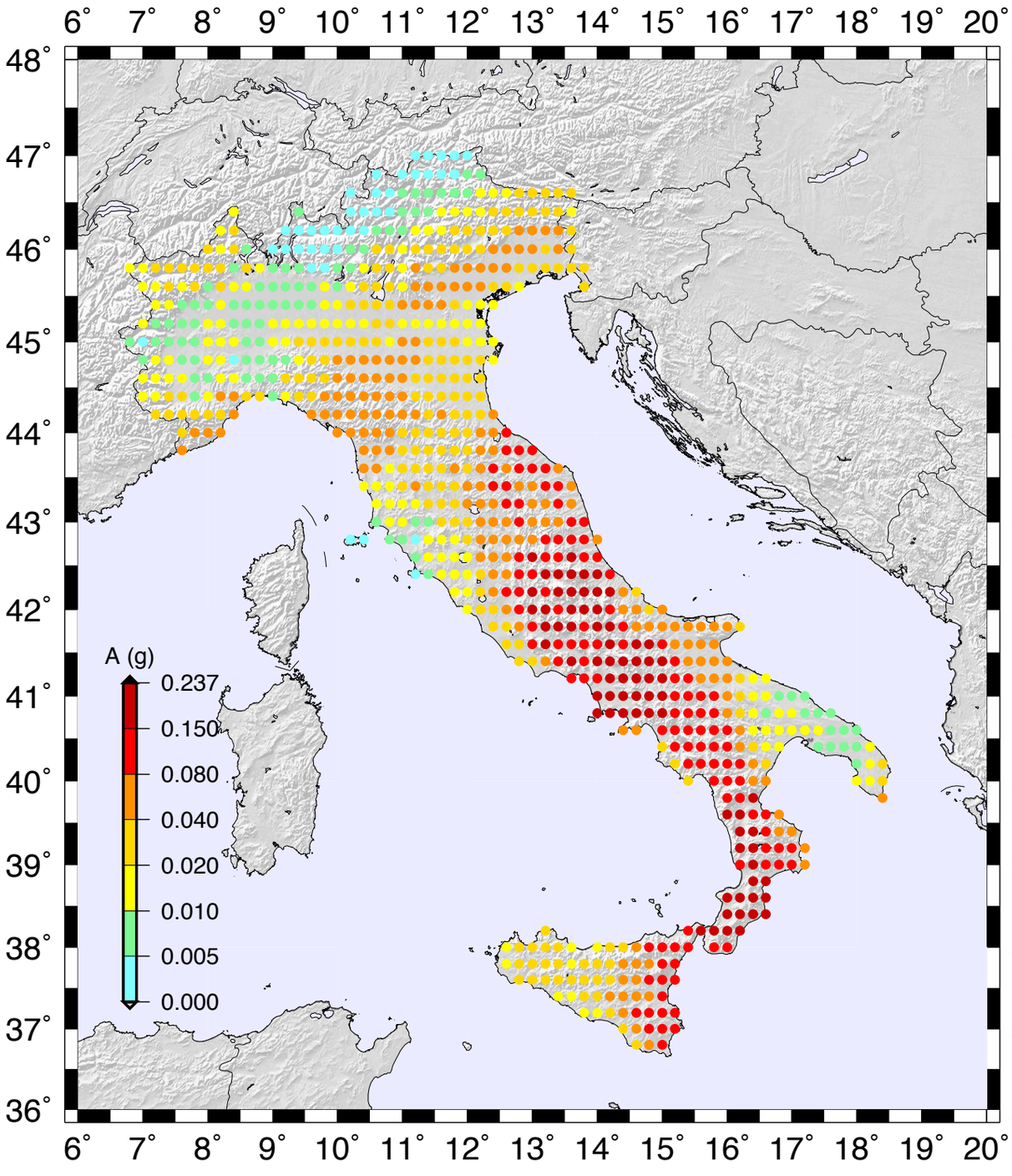
# Design Ground Acceleration (DGA)

- The procedure gives good results when applied to the case of the Irpinia 1980 earthquake. The DGA predicted by the modelling is similar the actual DGA obtained from recordings



# Acceleration

## Amplitude of Peaks from Time Series (1Hz)

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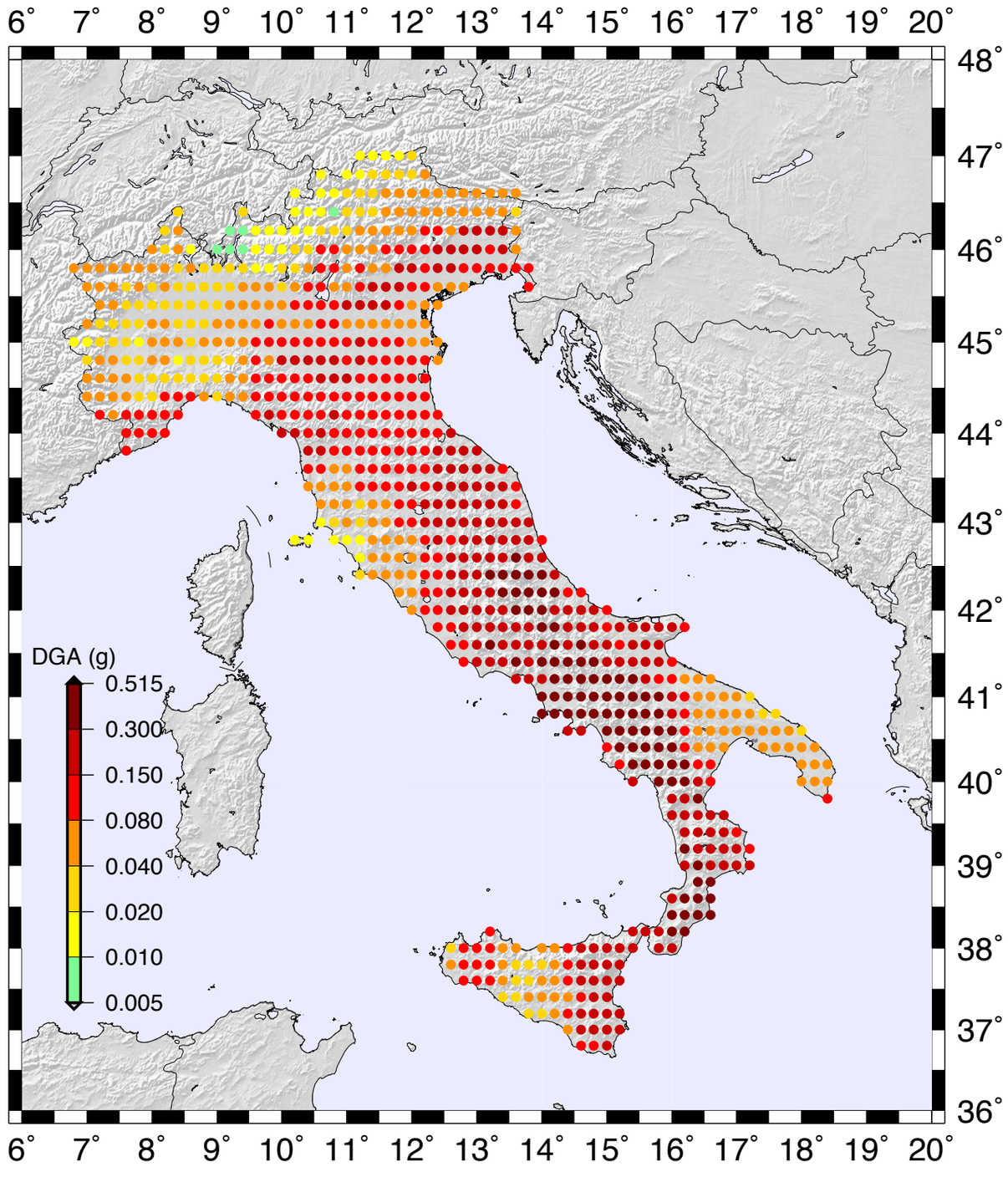
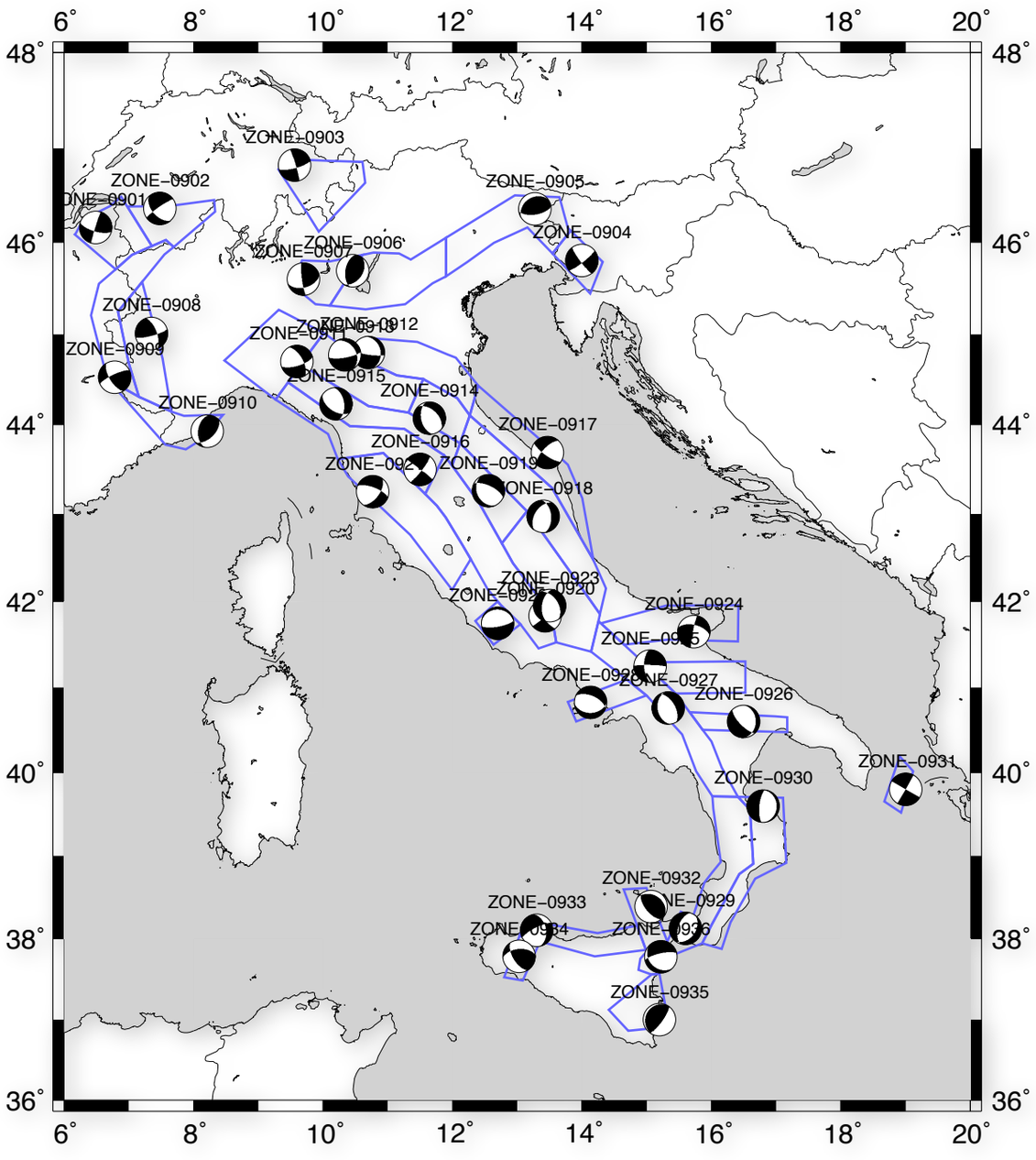
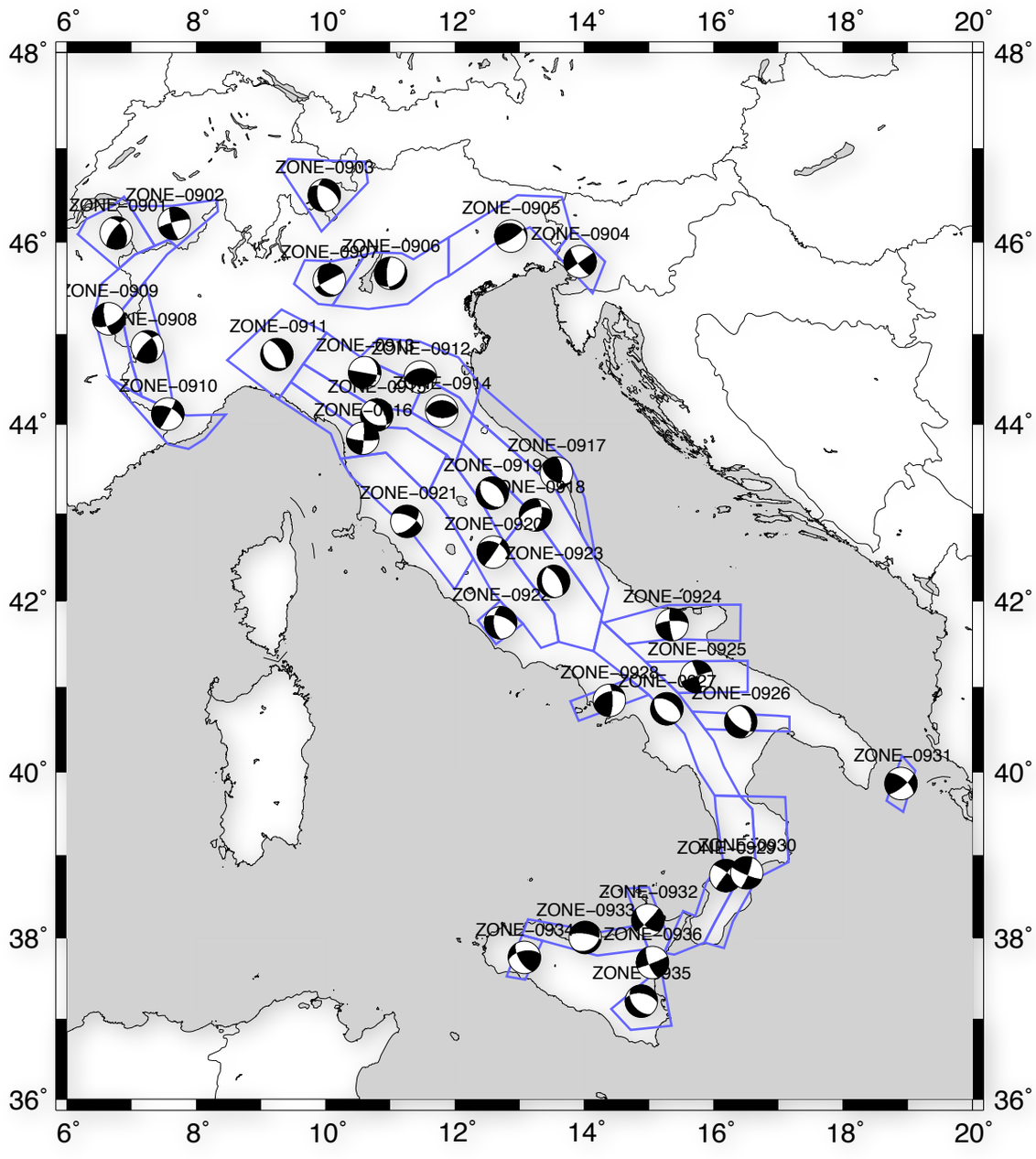


# Parametric Test on Source Mechanism

## Automatic Average

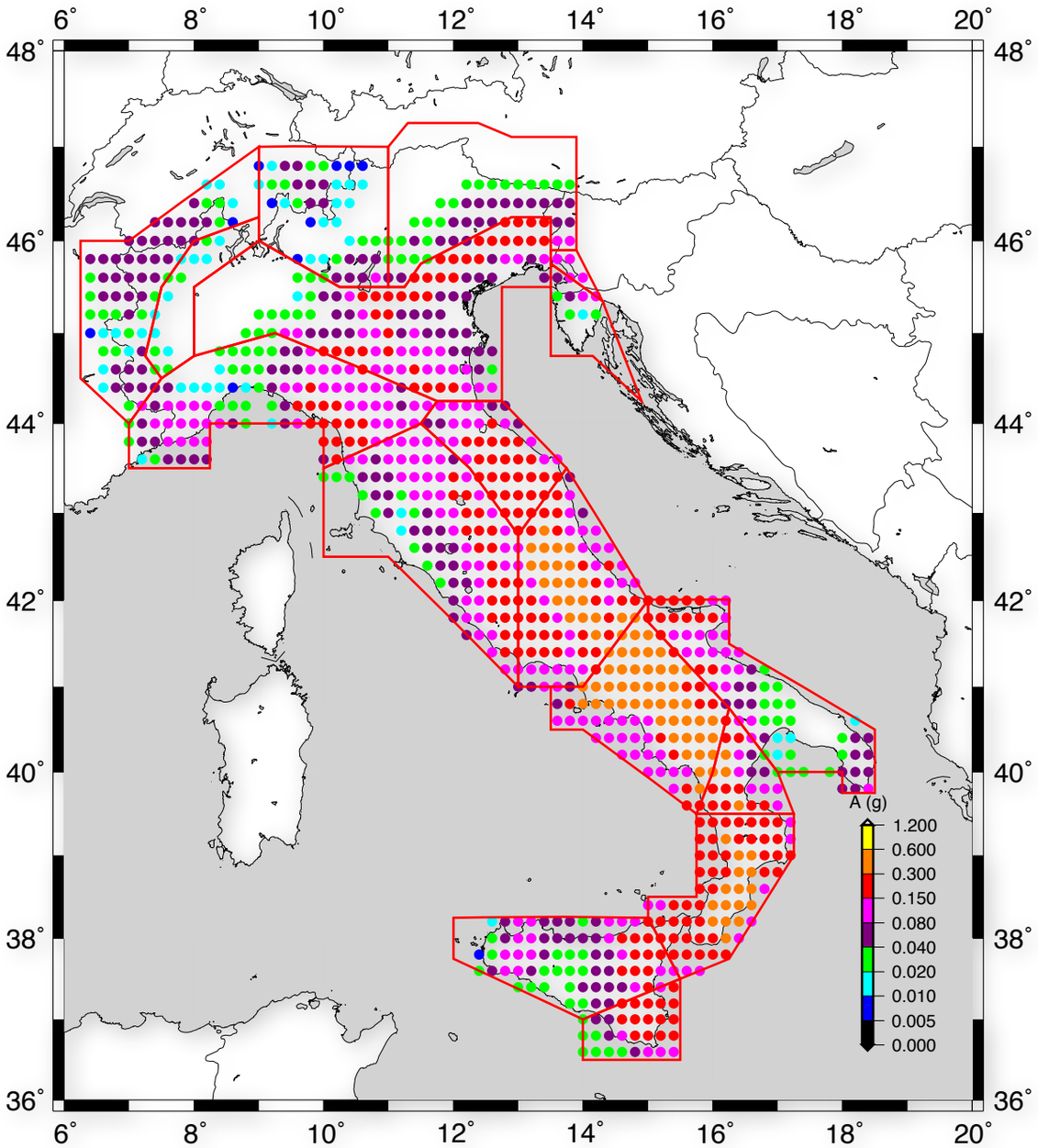



## Expert's Choice

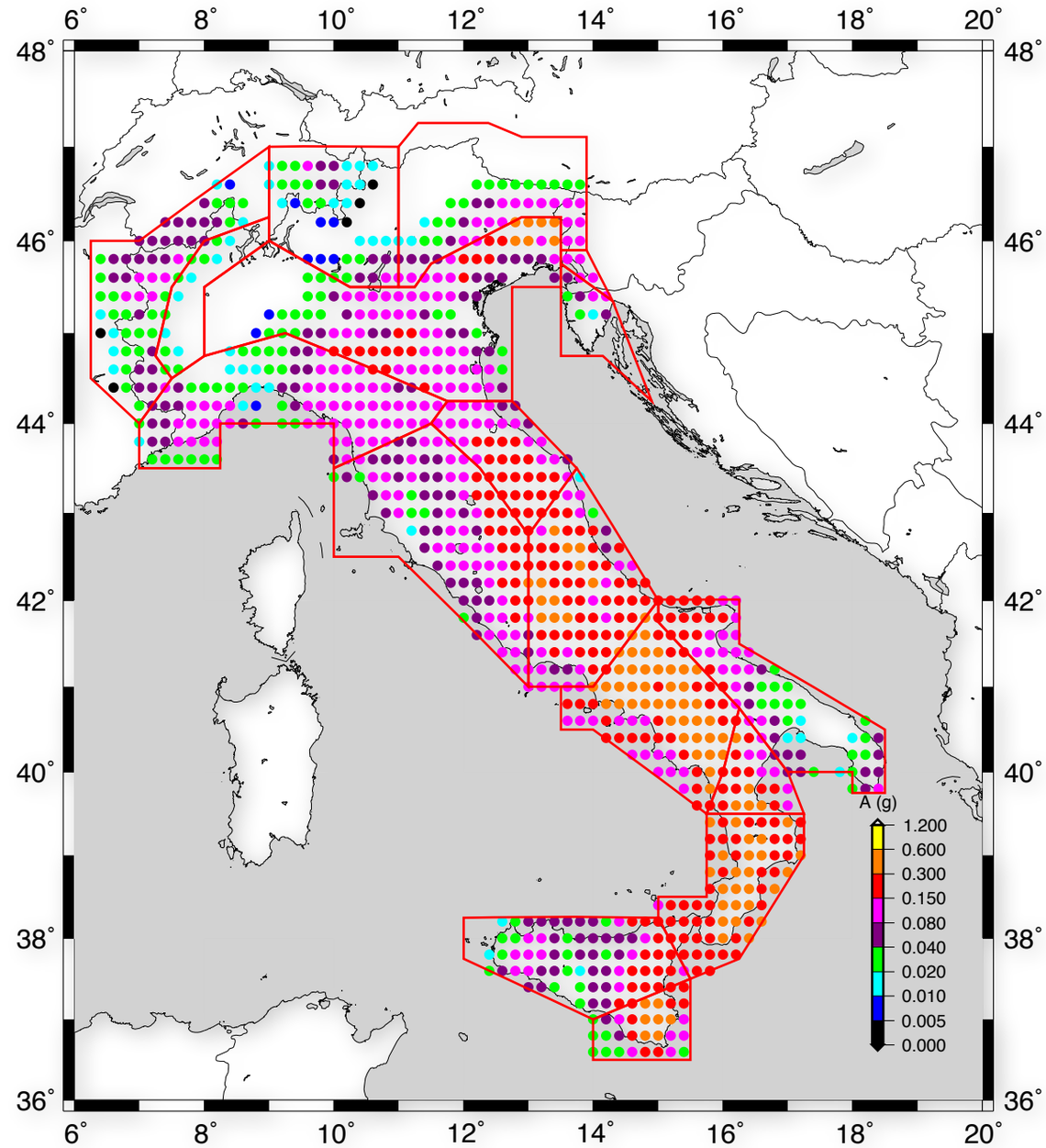


# Parametric Test on Source Mechanism

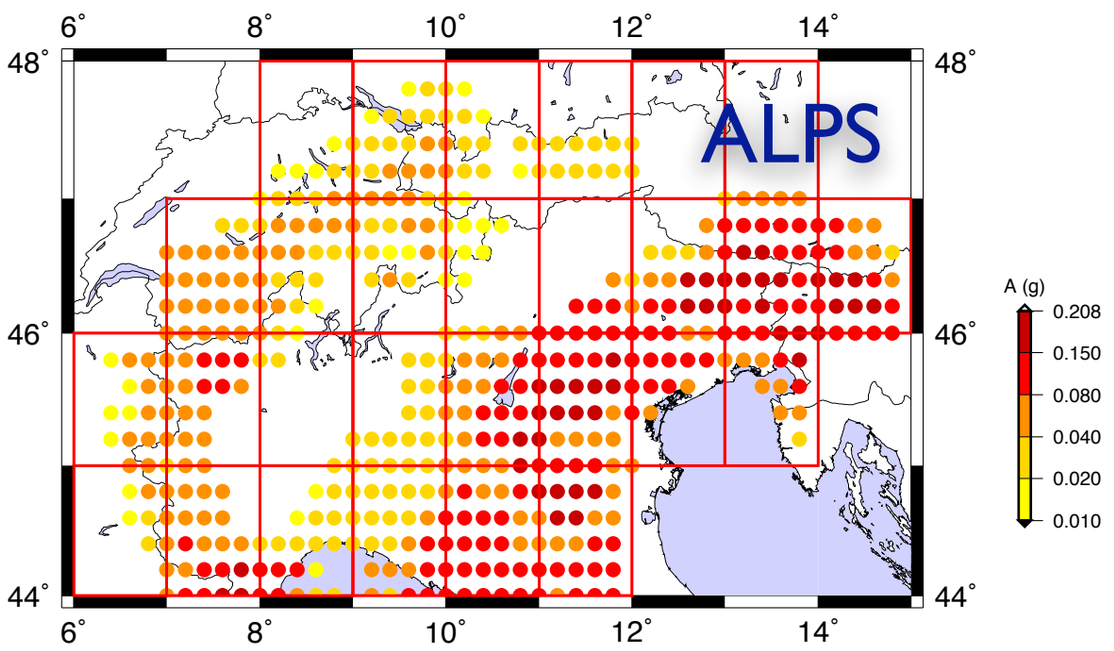
## Automatic Average

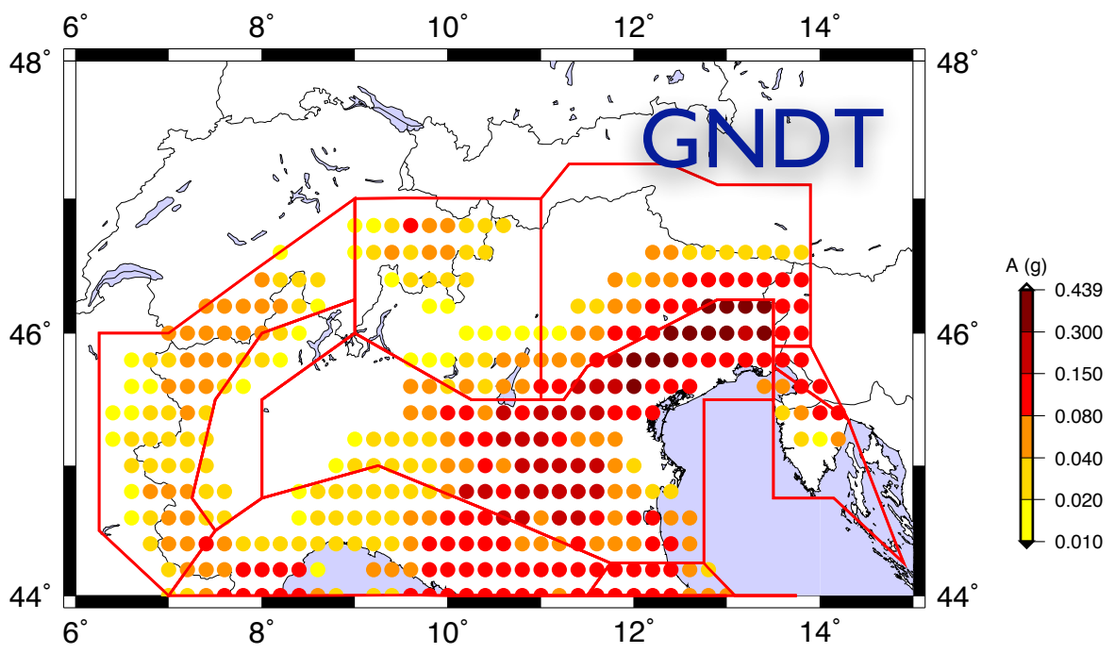



## Expert's Choice

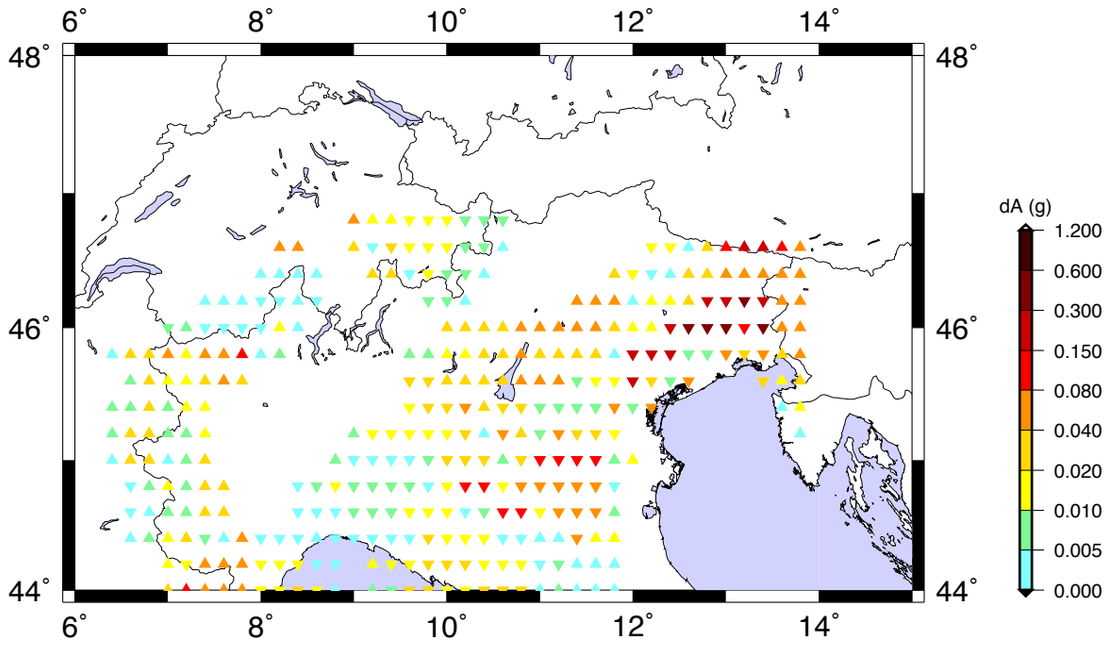


# Parametric Test on Structural Properties

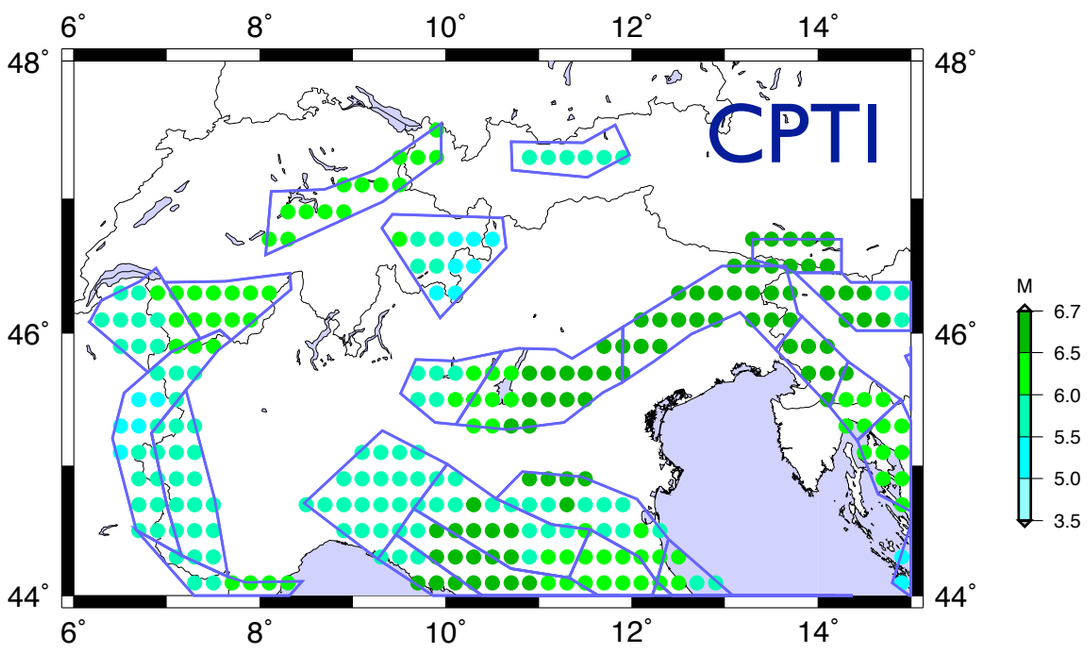


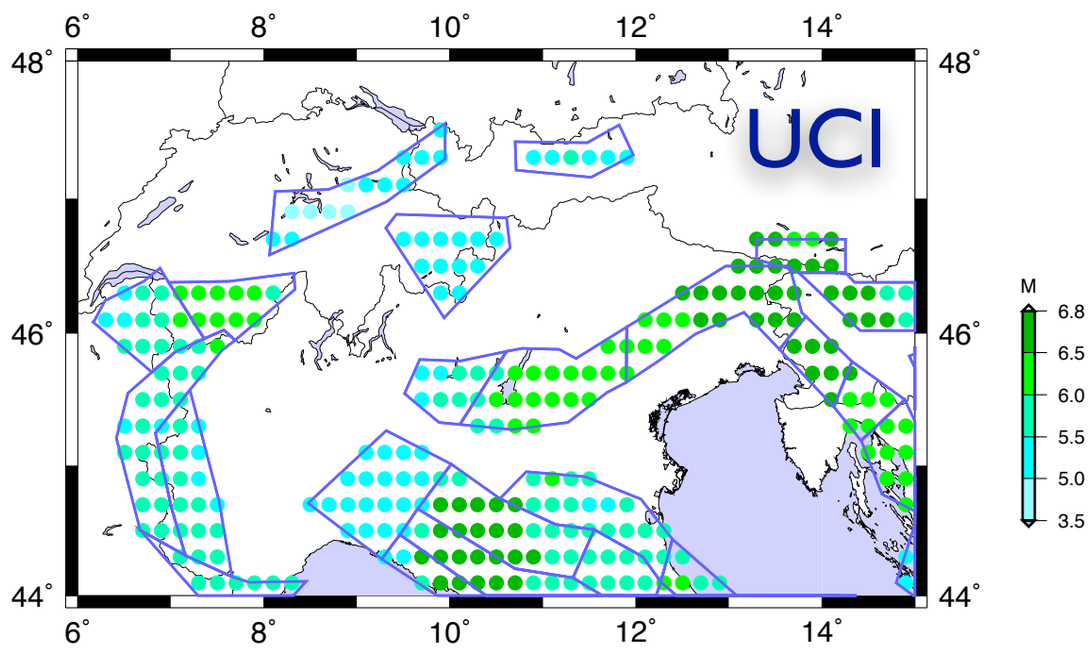




## ALPS - GNDT

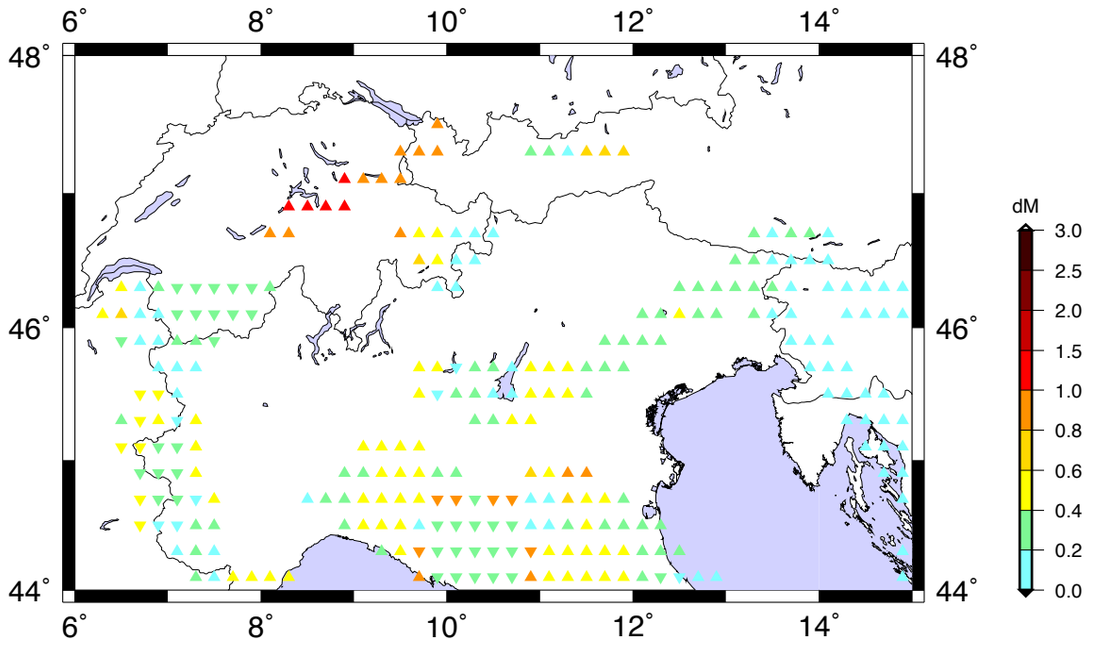


# Parametric Test on Earthquake Catalogue

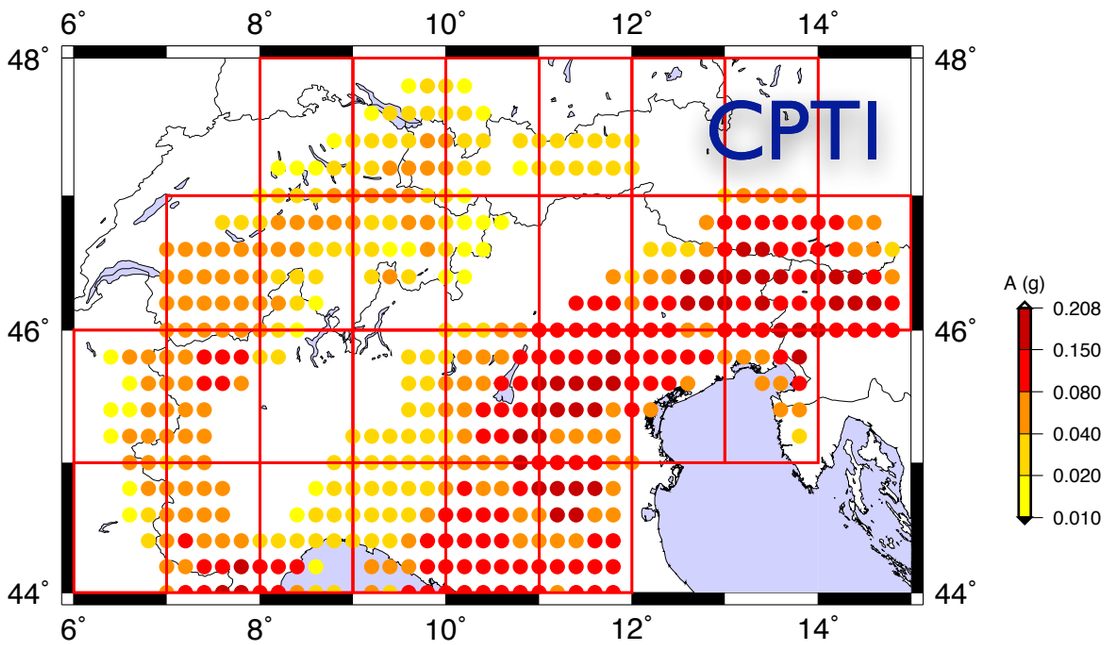


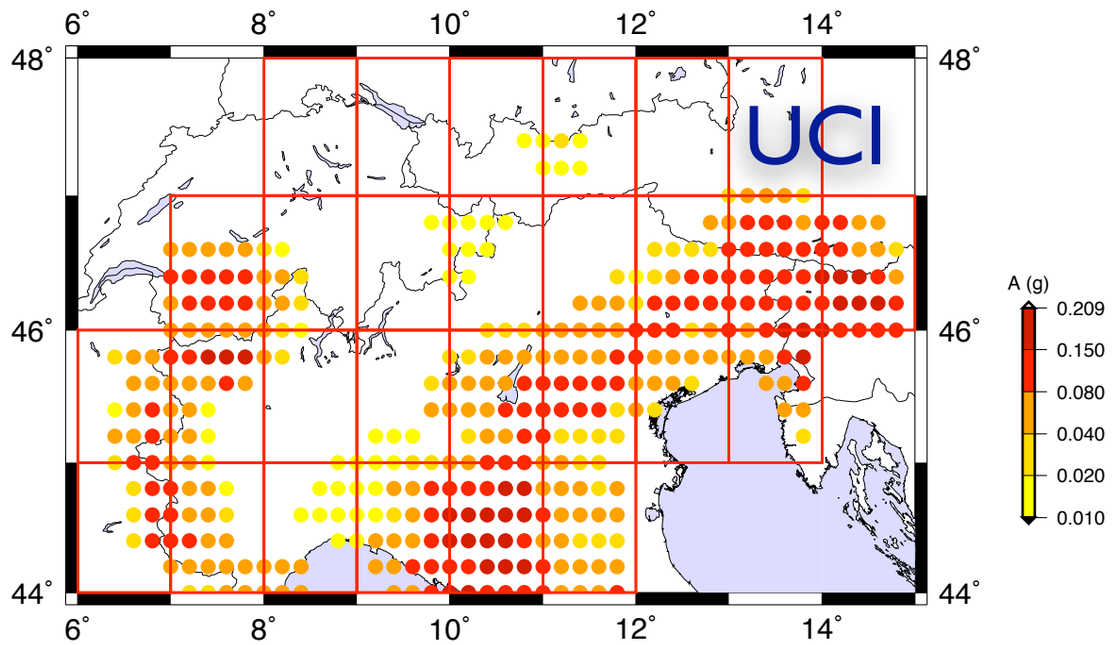




## CPTI - UCI

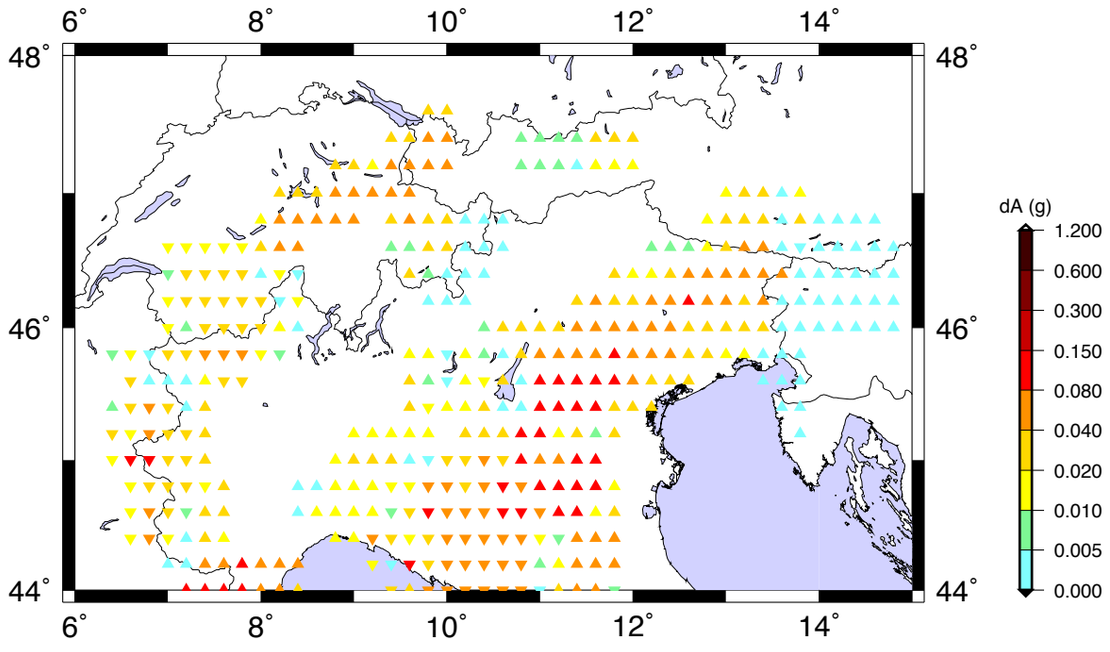


# Parametric Test on Earthquake Catalogue



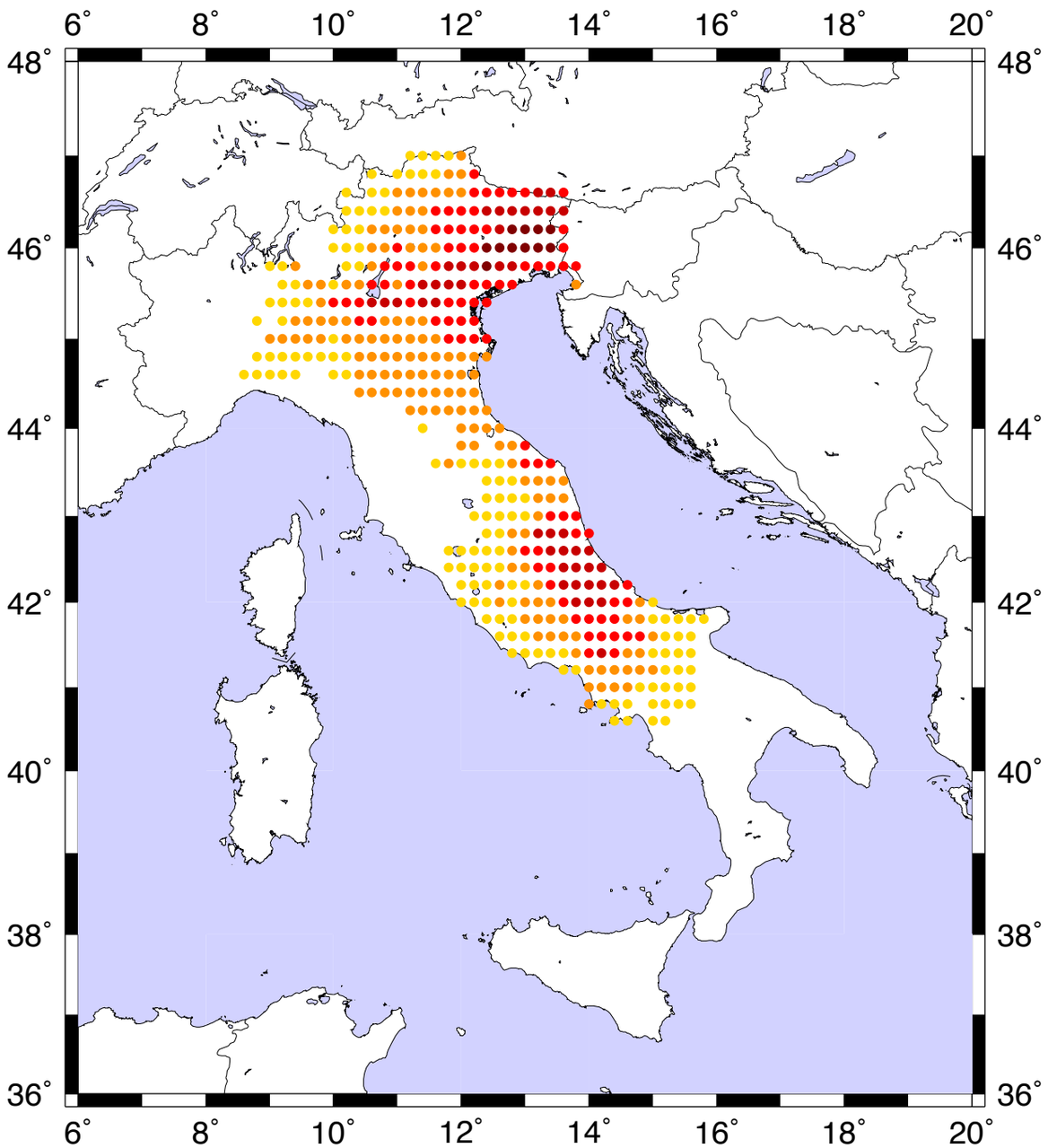




## CPTI - UCI

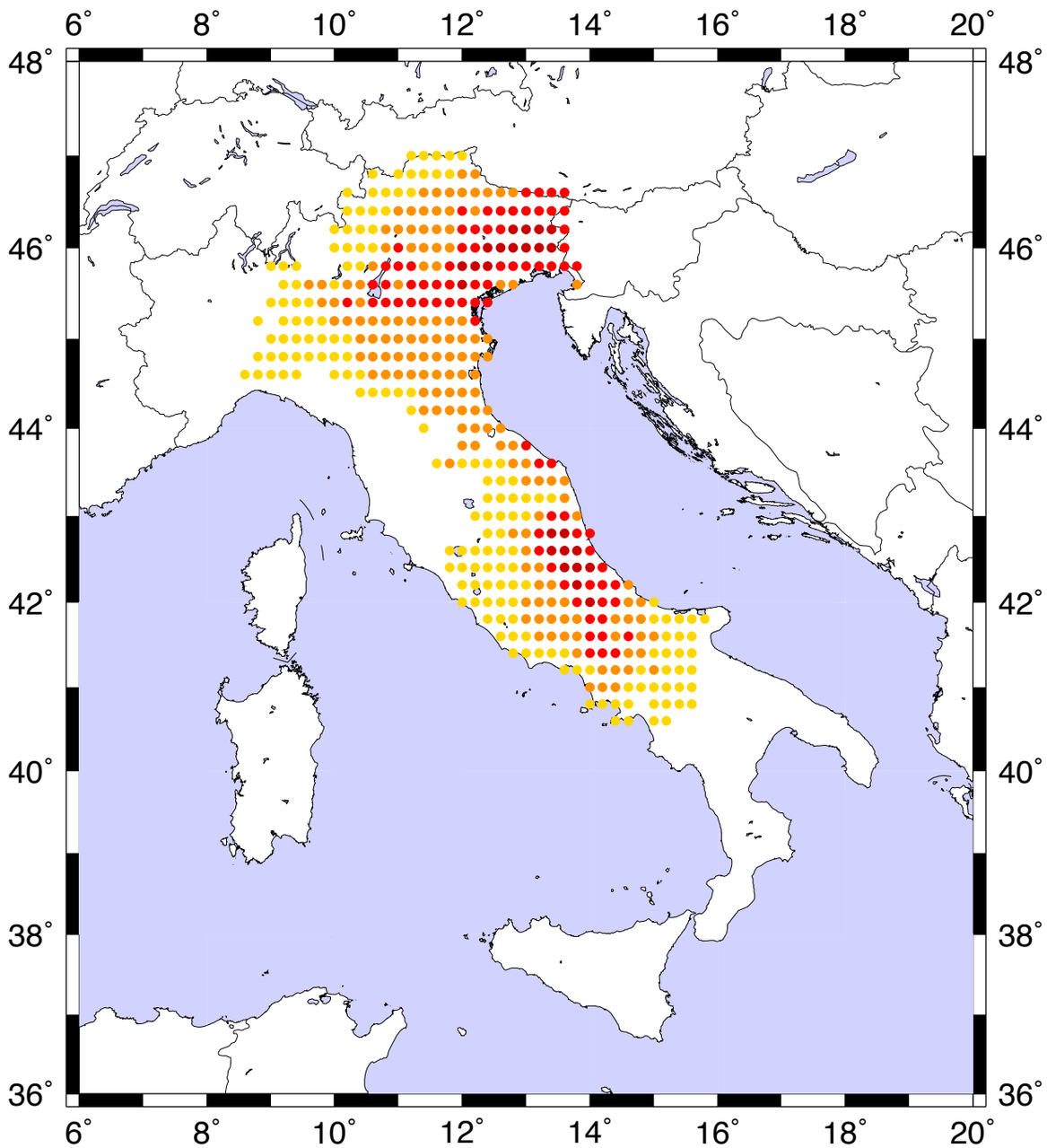


# Intensity Scenarios

NOR0309f1resamxing.int




NOR0309f1resamxisg.int



# Regional Scale - Homogeneity!

- If seismogenic zones are not defined according to homogeneous criteria, hazard results will be hardly comparable (source: GSHAP)

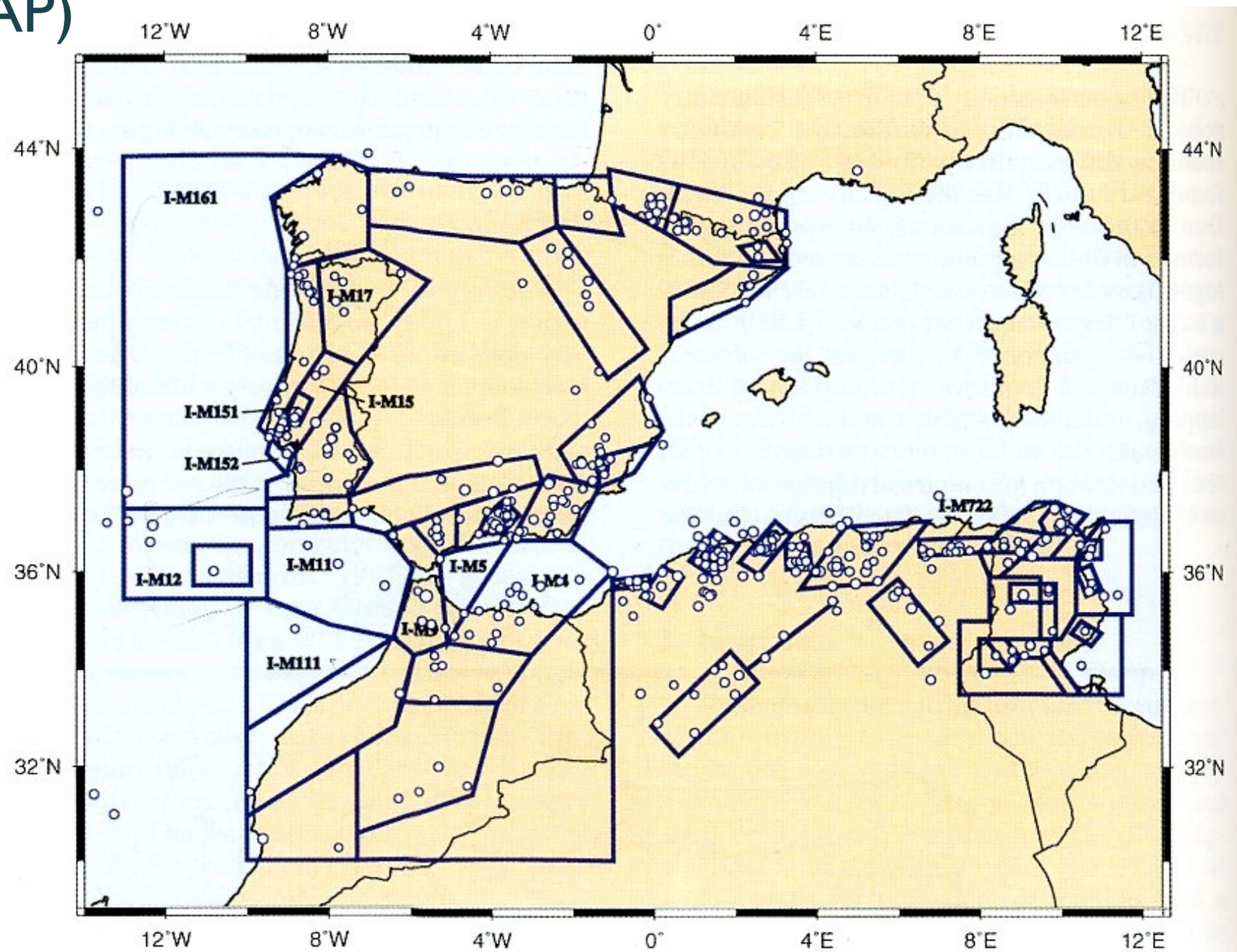
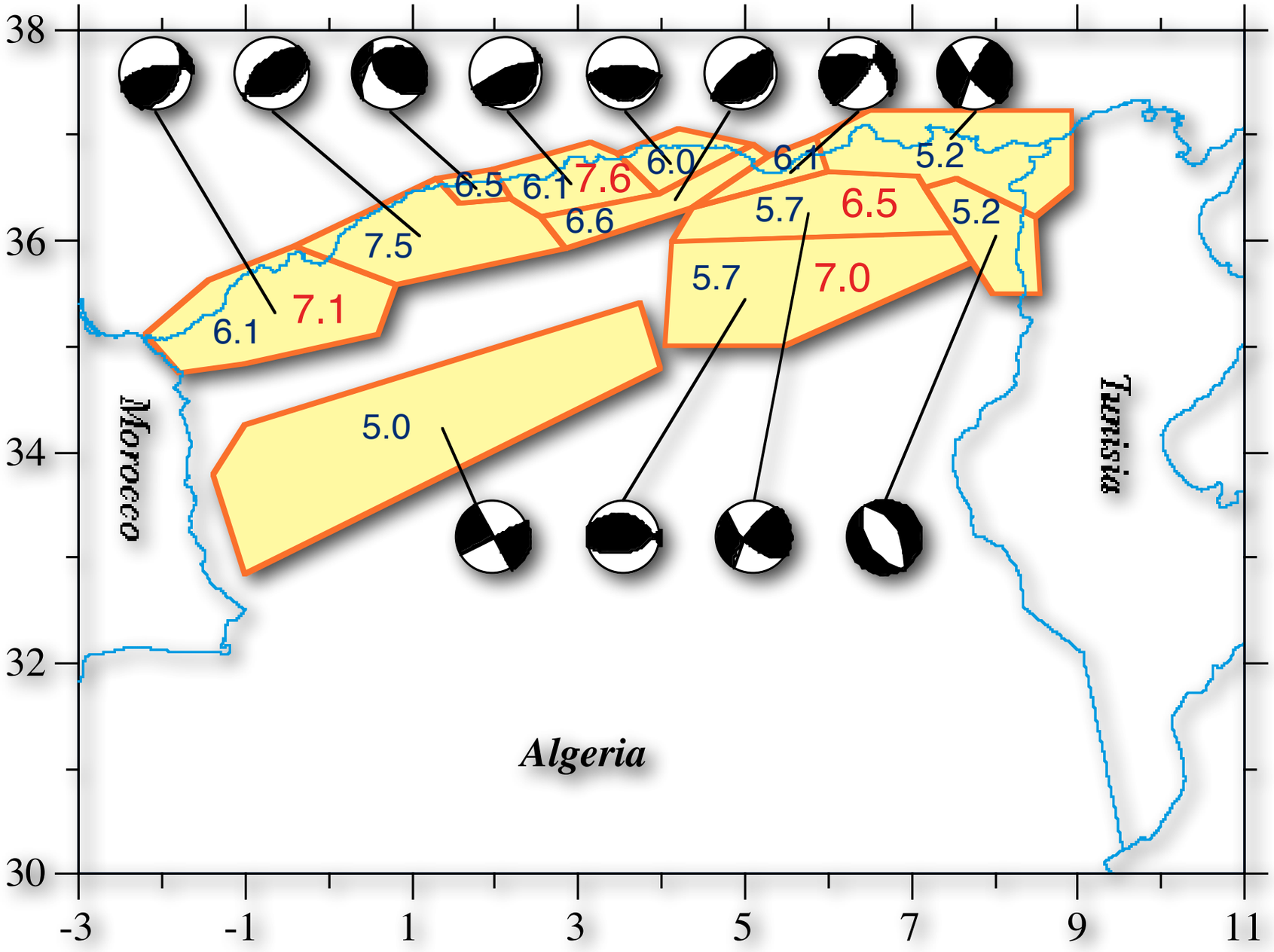



**Fig. 2.** Final distribution of earthquake source zones for the Ibero-Maghreb region, and epicenters of the generated List of Significant Earthquakes with $M \geq 4.5$ from 1900 to 1989.

# Regional Scale - Seismogenic Potential

- If the earthquake catalogue is not complete even in the high magnitude range, computations can be eventually performed analysing the seismogenic potential of the active faults



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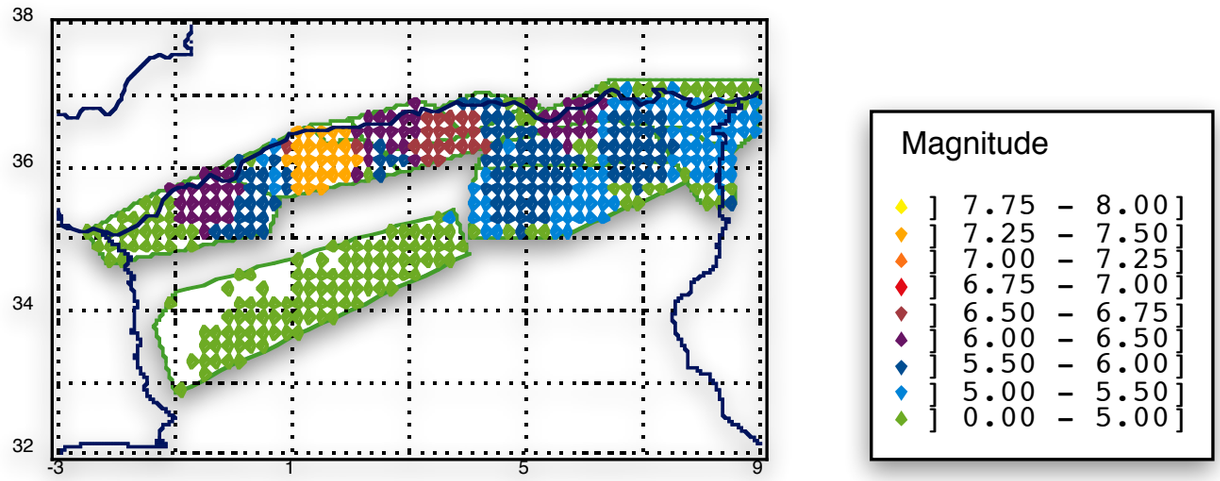
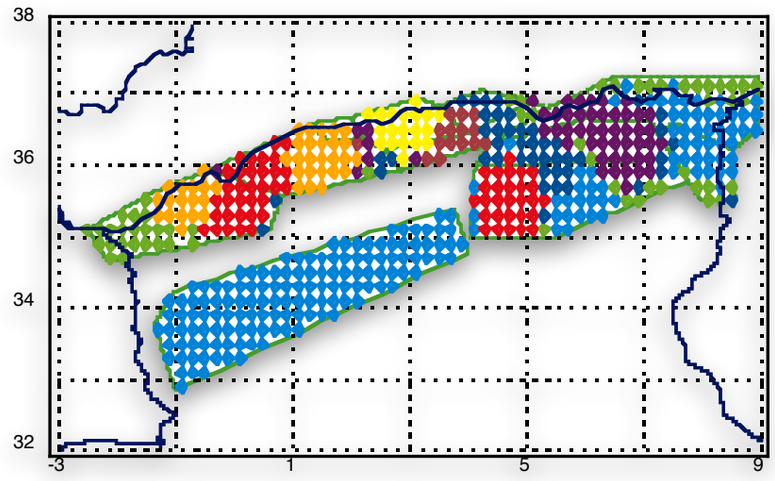
Max OBSERVED magnitude (smoothed)




Max EXPECTED magnitude (smoothed)



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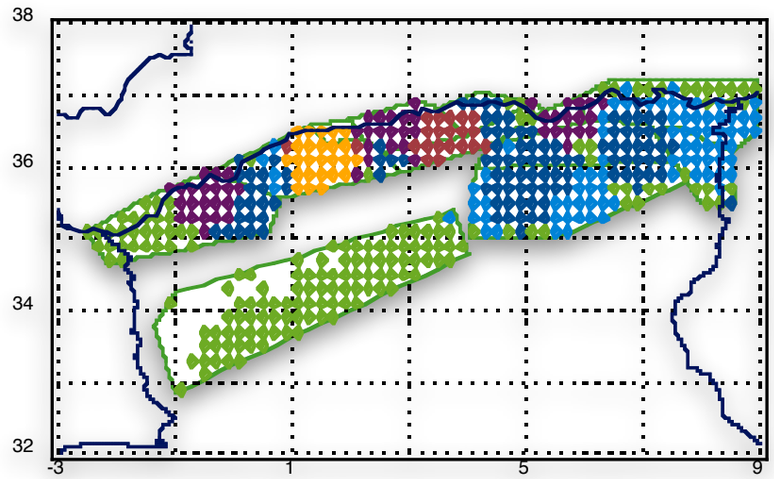


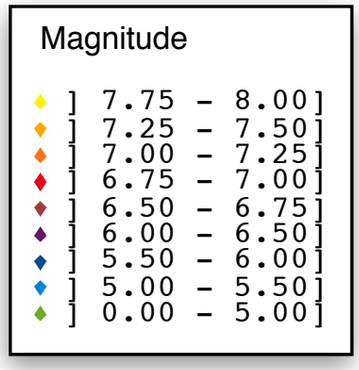


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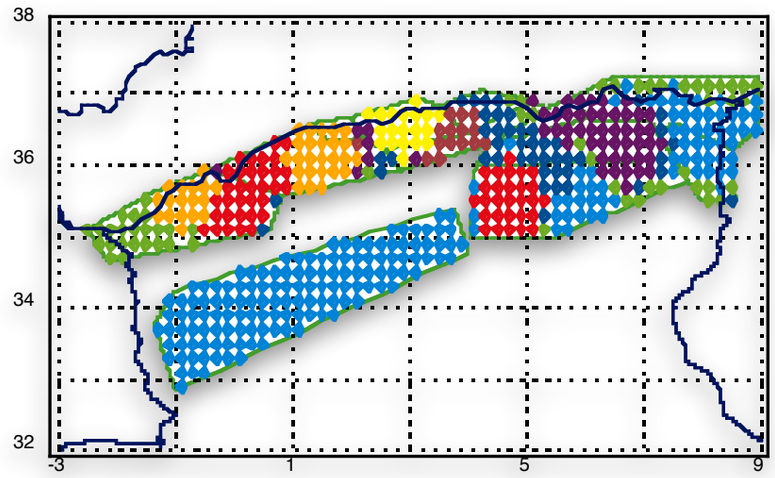
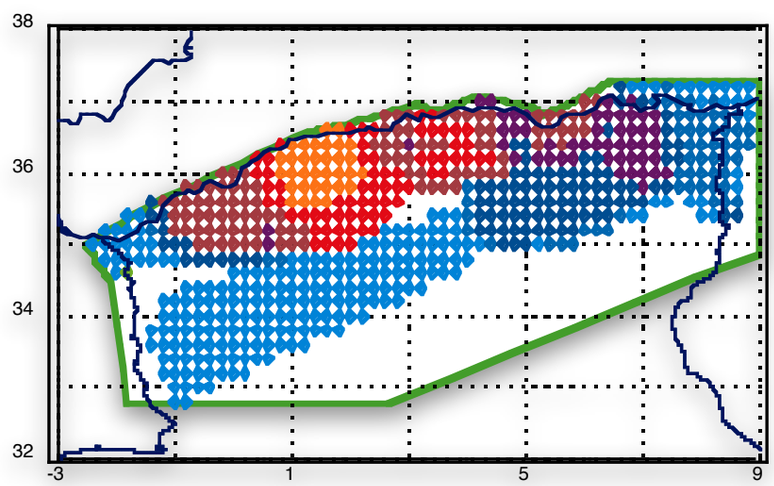
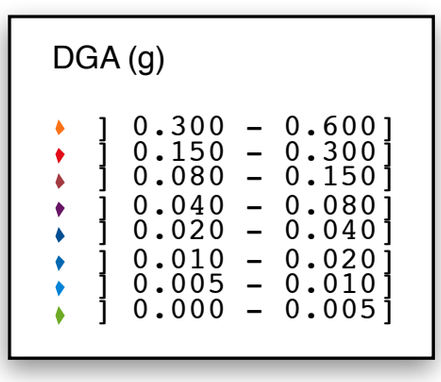
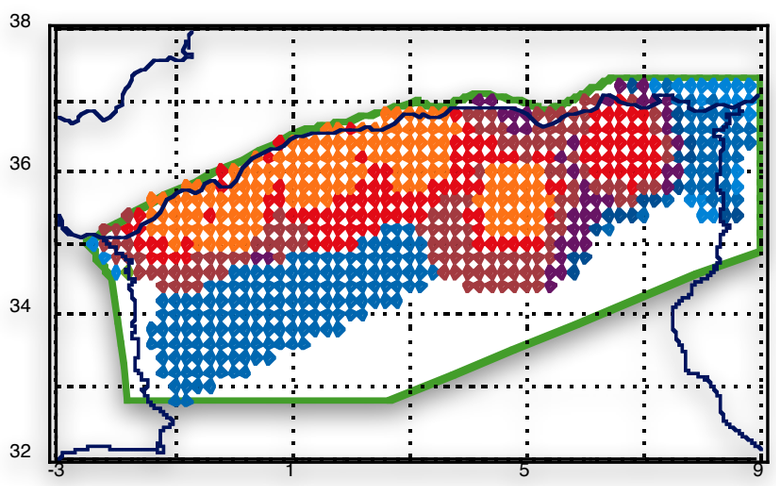


# Regional Scale - Future developments

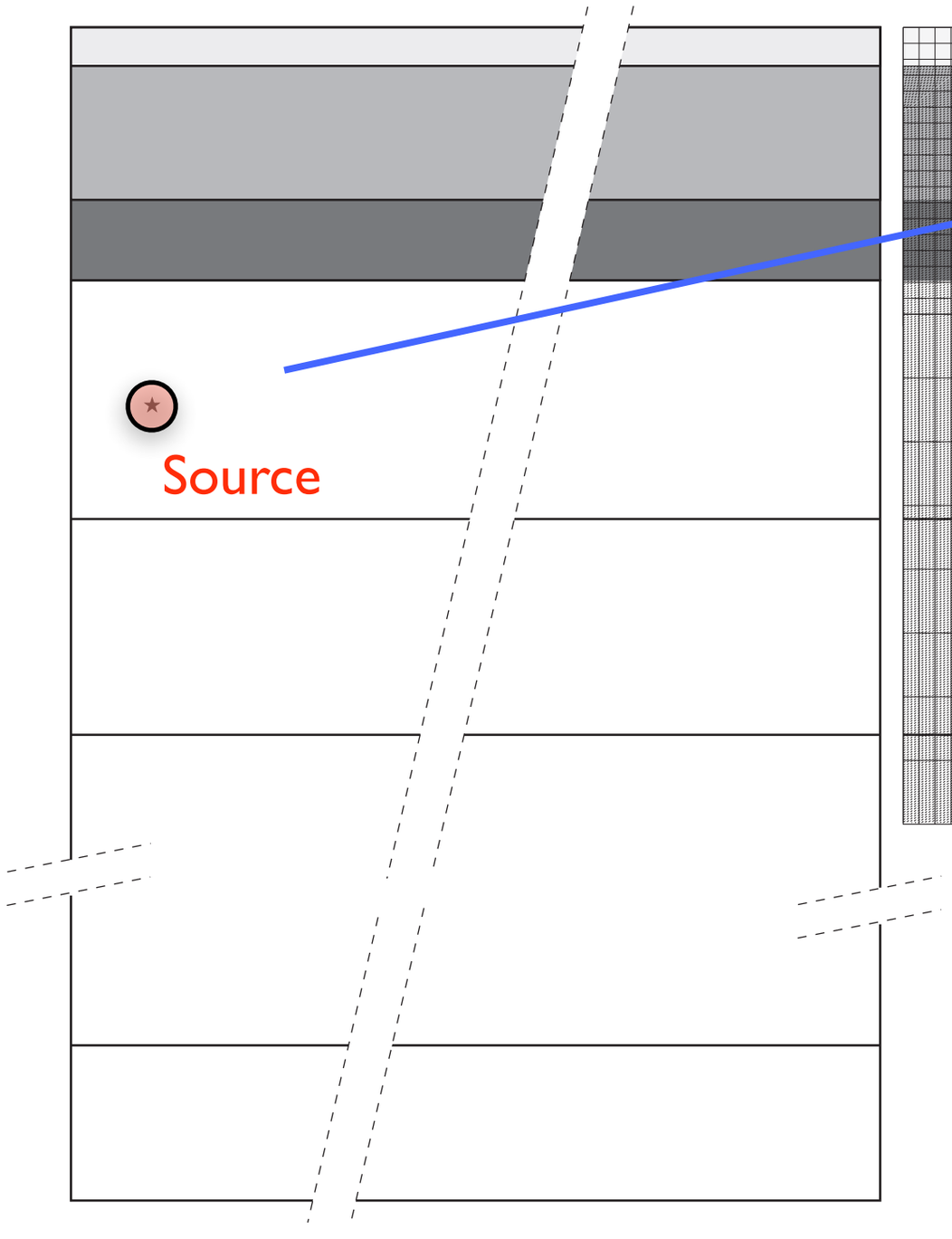
- Properly extend the computations to 10 Hz
- Take into account the effect of lateral heterogeneities (2D and 3D)
- Detailed source model, with multiple hypothesis about the rupture
- Further code optimization
- Import of the results into a fast DB for data analysis
- ...

# Local Scale - Introduction

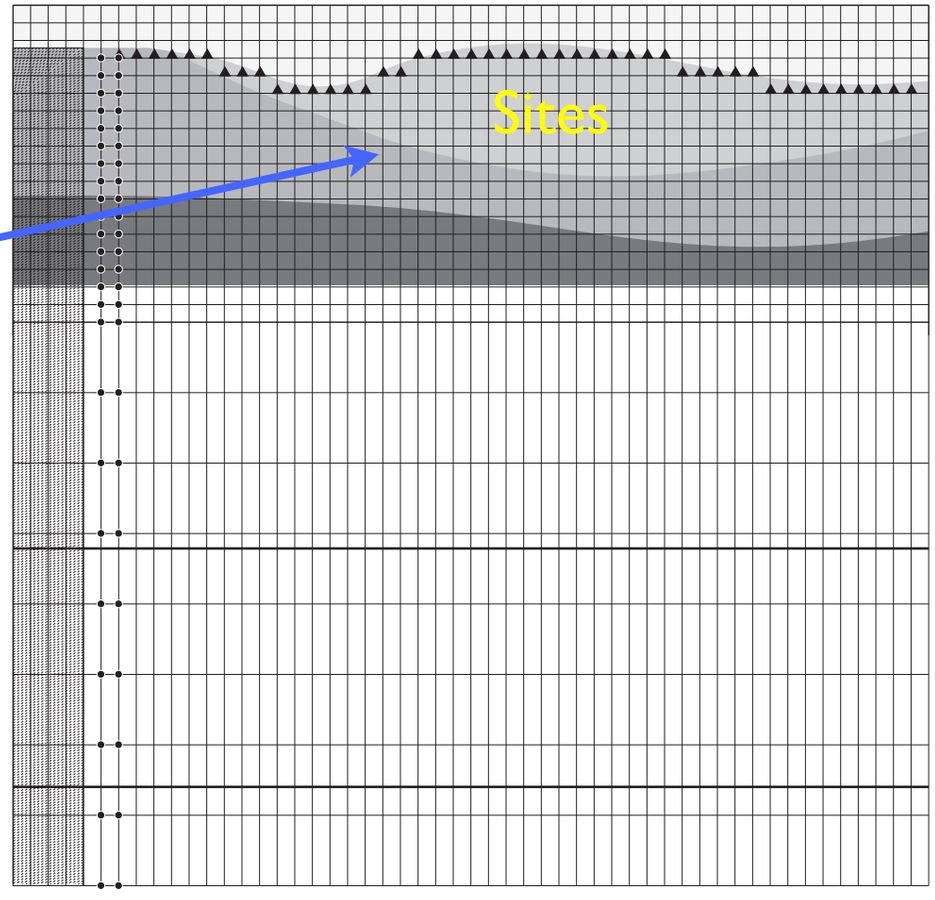
- Synthetic seismograms computed along selected profiles
- Laterally heterogeneous structural models
- Detailed source model
- Cut-off frequency up to 10 Hz
- Maps of ground motion amplification
- Hybrid technique (modal summation + finite difference)

# Local Scale - Definition of Model

## Modal Summation




## Finite Difference

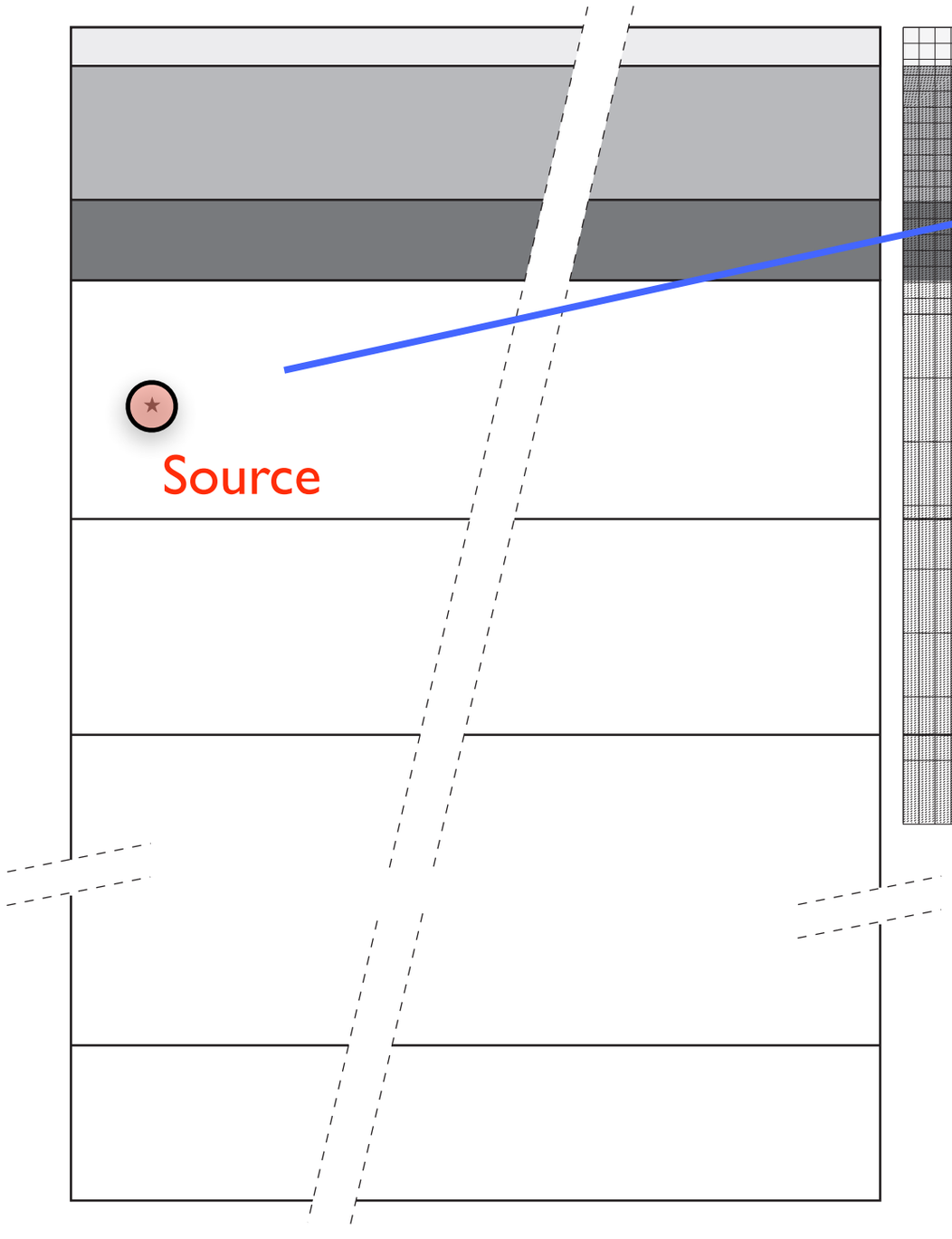



★ Source
• Input for FD computations
▲ Sites
Absorbing boundary

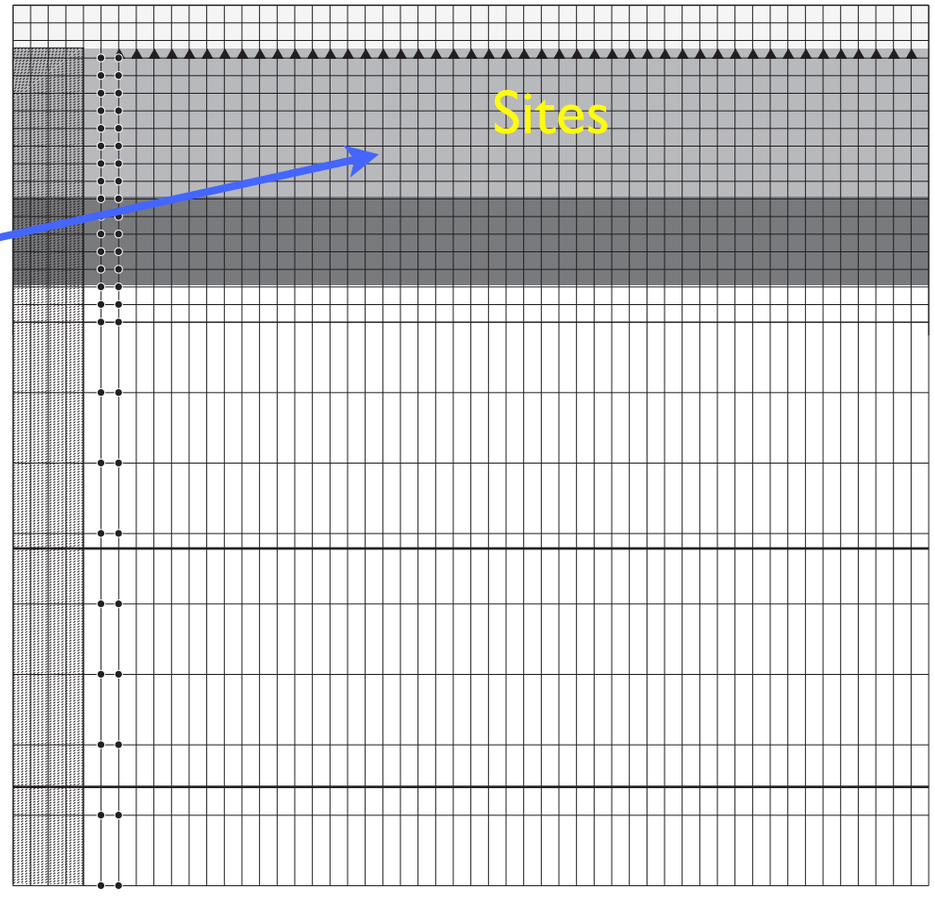
| Material | Density (g/cm$^3$) | Vp (km/s) | Qp | Vs (km/s) | Qs |
|---|---|---|---|---|---|
| Air | 0 | 0 | 0 | 0 | 0 |
| Sed1 | 1.8 | 0.8 | 100 | 0.4 | 50 |
| Sed2 | 1.9 | 0.9 | 100 | 0.5 | 50 |
| Sed3 | 2.0 | 1.0 | 100 | 0.6 | 50 |

# Local Scale - Definition of Model

## Modal Summation




## Finite Difference




★ Source

• Input for FD computations

▲ Sites

Absorbing boundary

| Material | Density (g/cm$^3$) | Vp (km/s) | Qp | Vs (km/s) | Qs |
|---|---|---|---|---|---|
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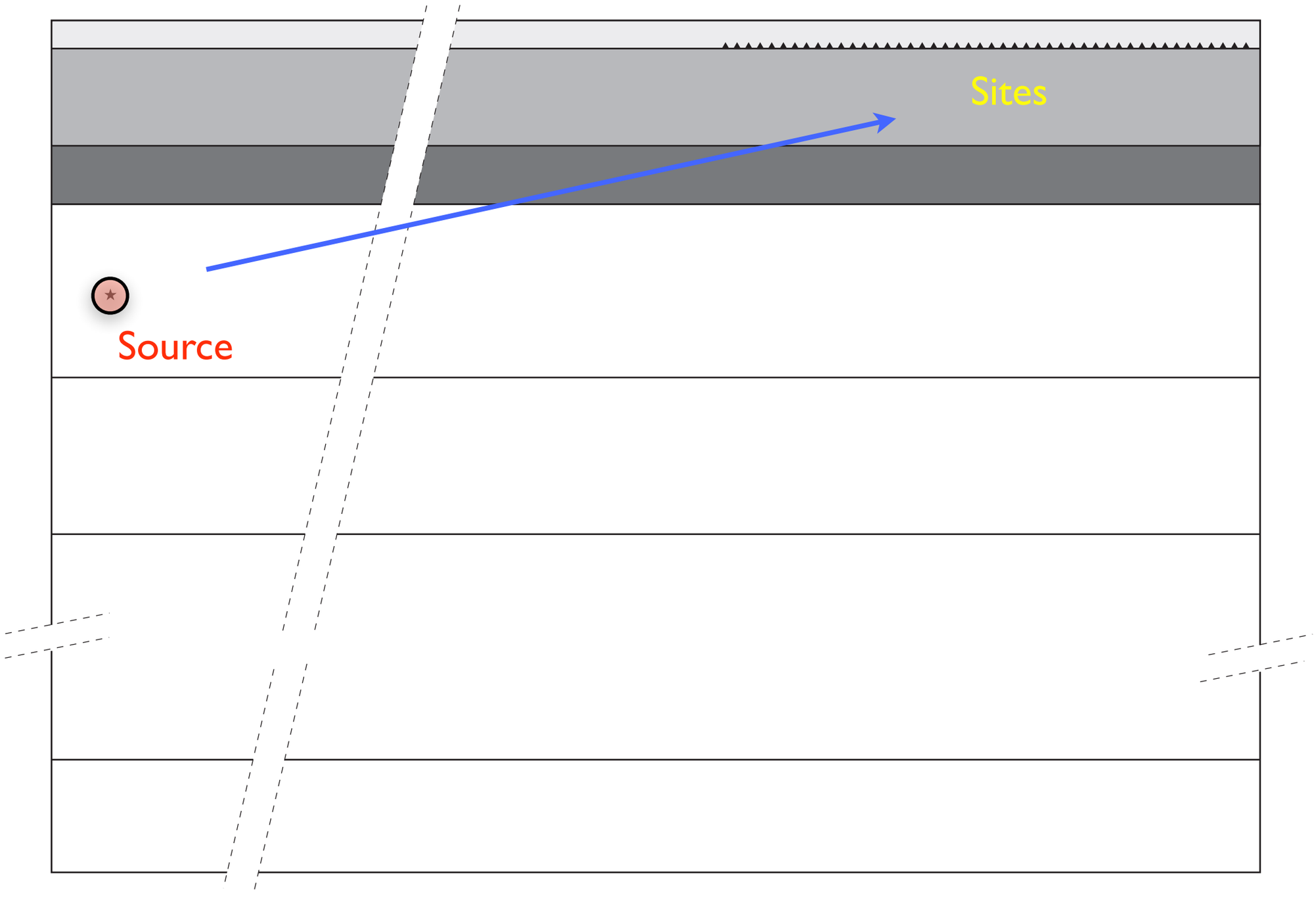
| Sed1 | 1.8 | 0.8 | 100 | 0.4 | 50 |
| Sed2 | 1.9 | 0.9 | 100 | 0.5 | 50 |
| Sed3 | 2.0 | 1.0 | 100 | 0.6 | 50 |

# Local Scale - Definition of Model

## Modal Summation



# Local Scale - Input Definition

```
Parameters file for program pfdg10
--------------------------------------------------------------------------
Modal summation model
--------------------------------------------------------------------------
test.spr                          Modes for 1D structure
0         First mode to use (1=fundamental, 0=all)
0         Last mode to use (0=all)
10.0      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
5.000     Source depth (km)
125.0     strike-receiver angle (SH modelling)
45.0      fault dip             (SH modelling)
90.0      fault rake            (SH modelling)
125.0     strike-receiver angle (P-SV modelling)
45.0      fault dip             (P-SV modelling)
90.0      fault rake            (P-SV modelling)
7.5       Source-2D model origin distance (km)
--------------------------------------------------------------------------
```

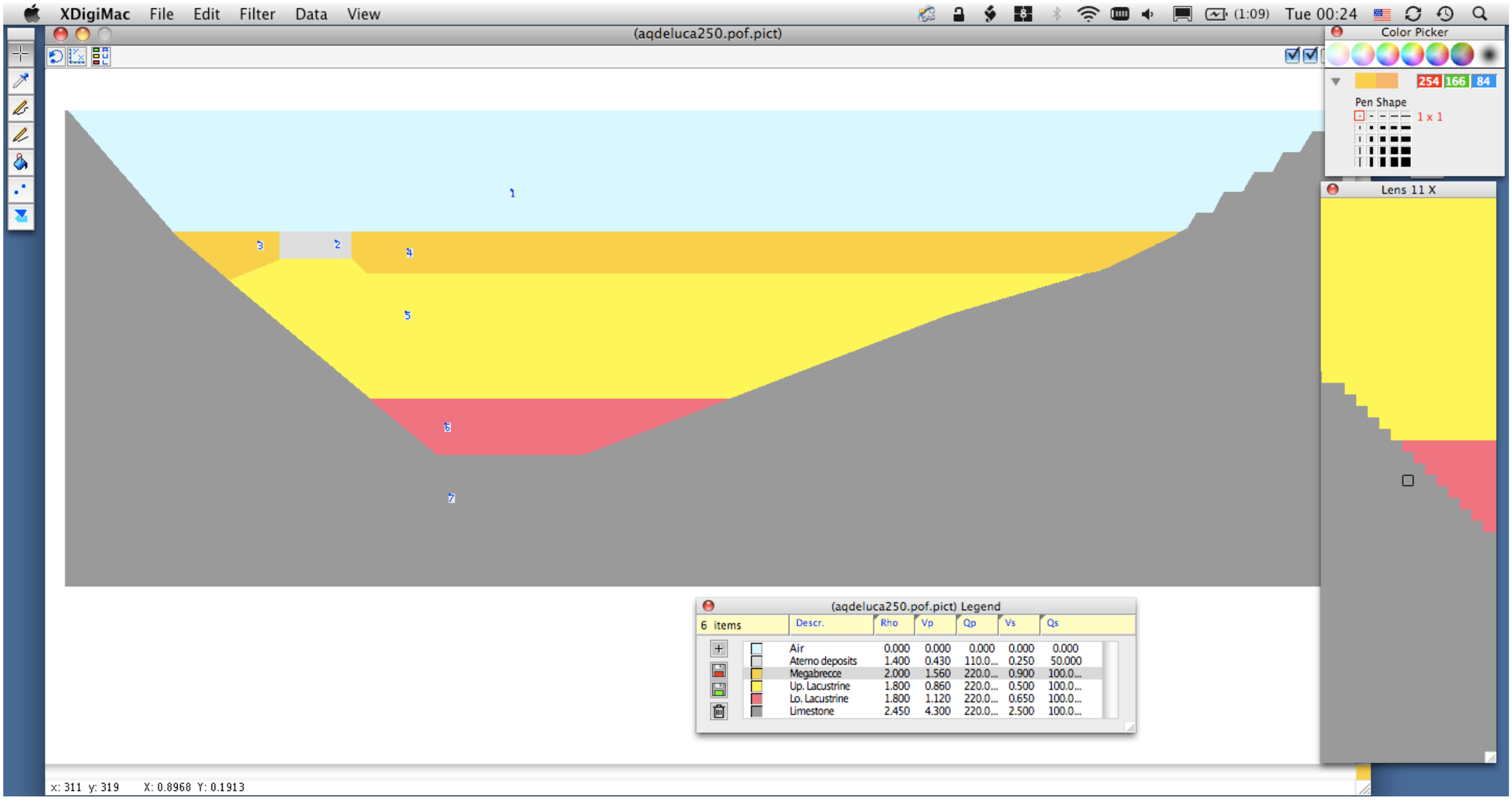
Modal Summation

```
Finite differences model
--------------------------------------------------------------------------
test                           Generated FD model
test.pof                      Polygons with 2D part definition
2800      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)
0.000     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)
10        Time window length (s) for 1D SH (0=auto)
10        Time window length (s) for 1D P-SV (0=auto)
10        Time window length (s) for 2D SH (0=auto)
10        Time window length (s) for 2D P-SV (0=auto)
00        Shift in origin time (SH)
00        Shift in origin time (P-SV)
--------------------------------------------------------------------
```

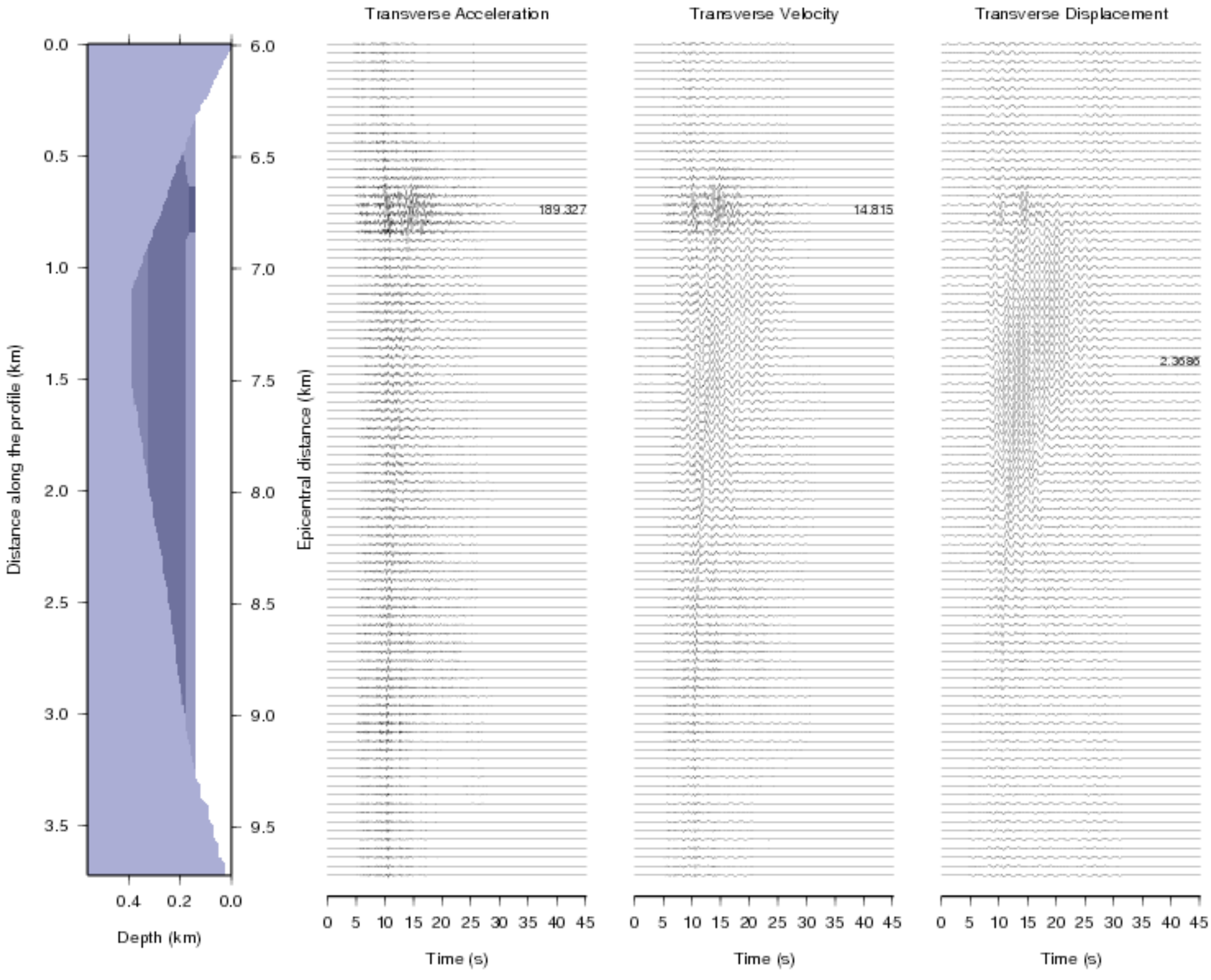
Finite Difference

# Local Scale - Input Definition

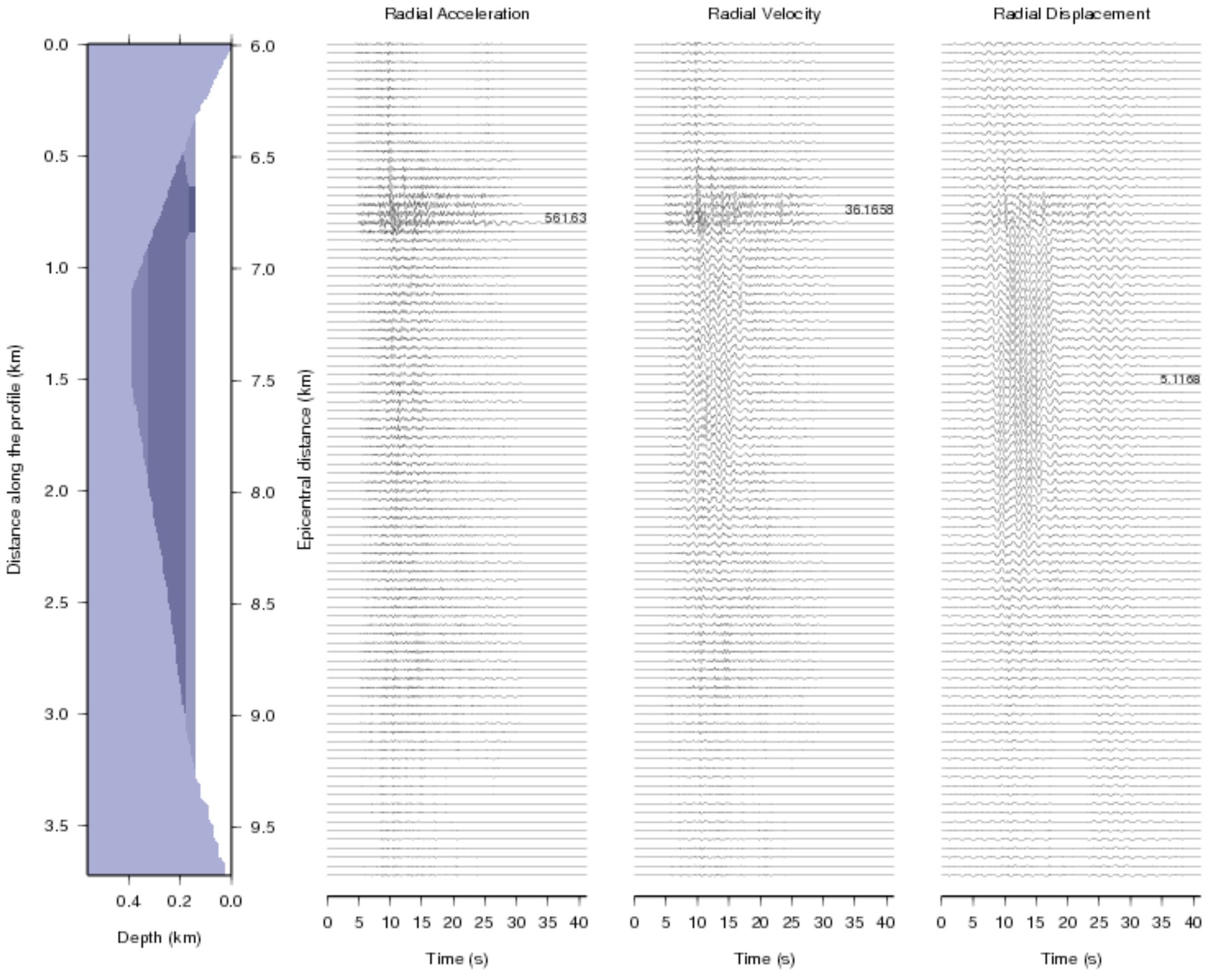
Ad-hoc software dedicated to the digitization of the layer geometry and the definition of the layer properties



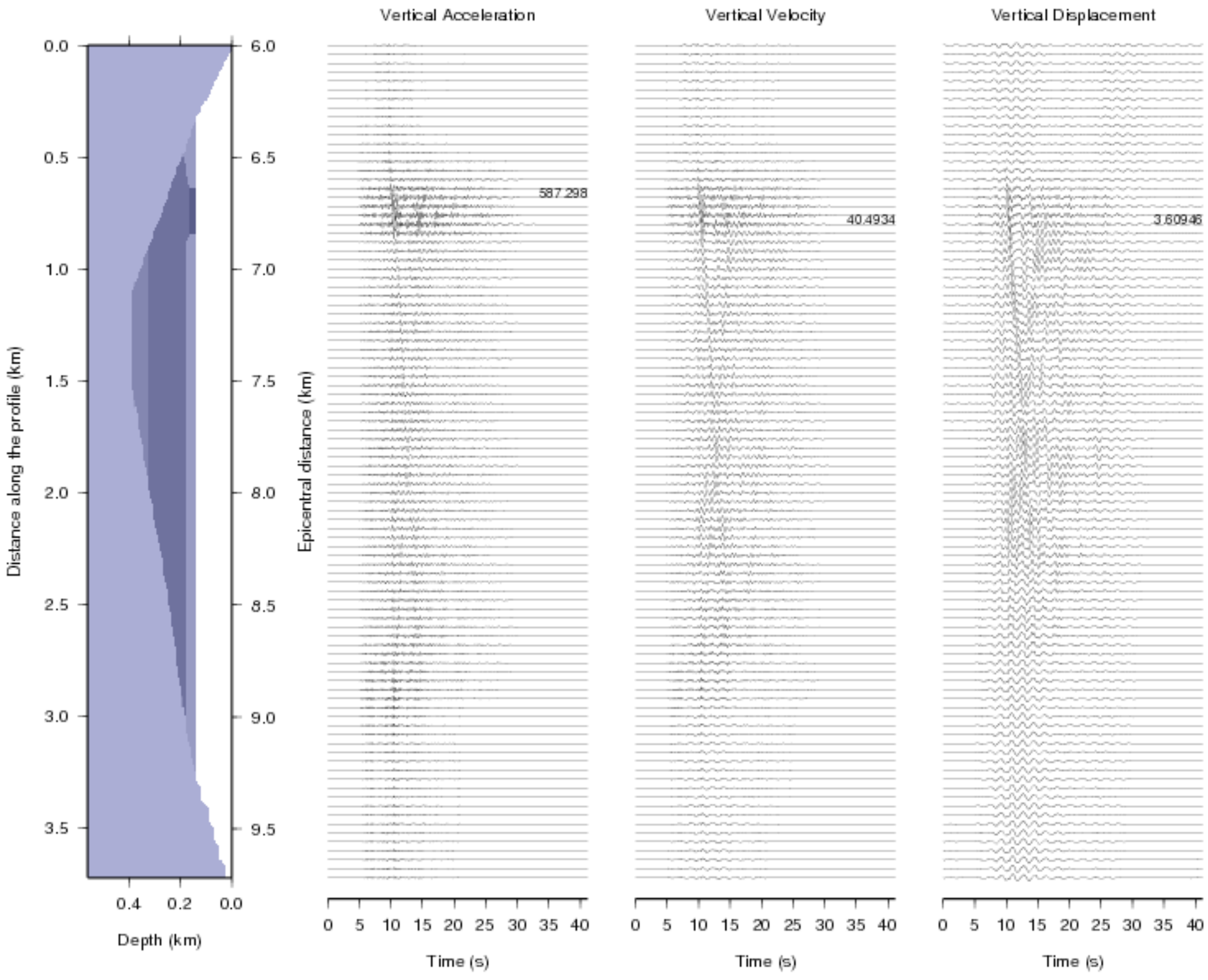
# Modelling - Transverse Component



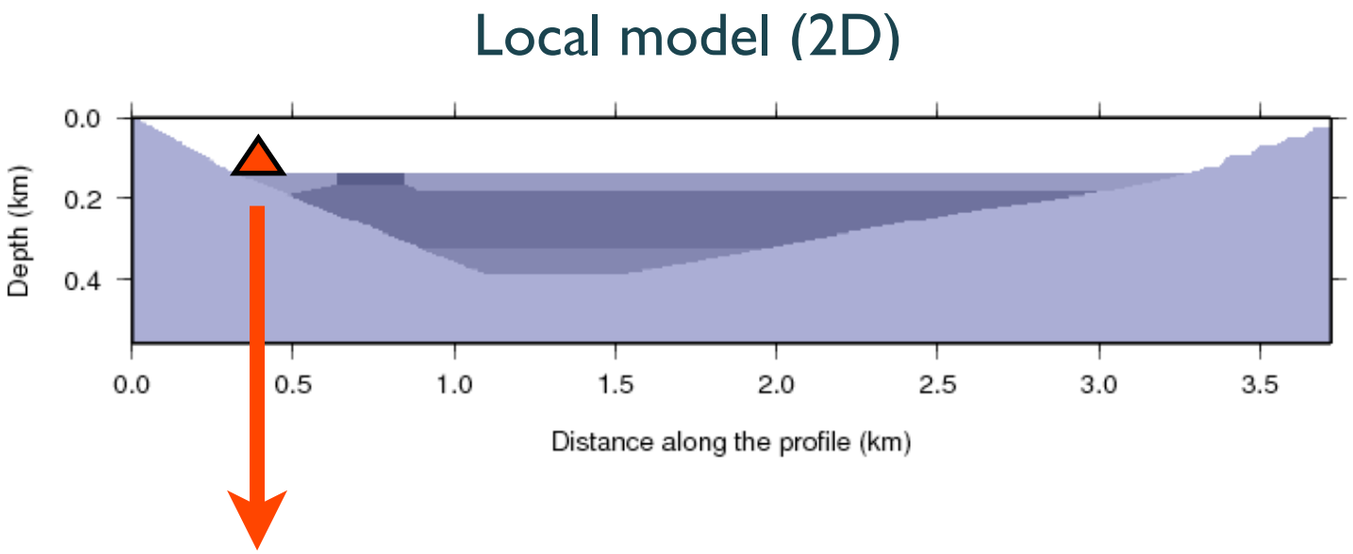
# Modelling - Radial Component



# Modelling - Vertical Component



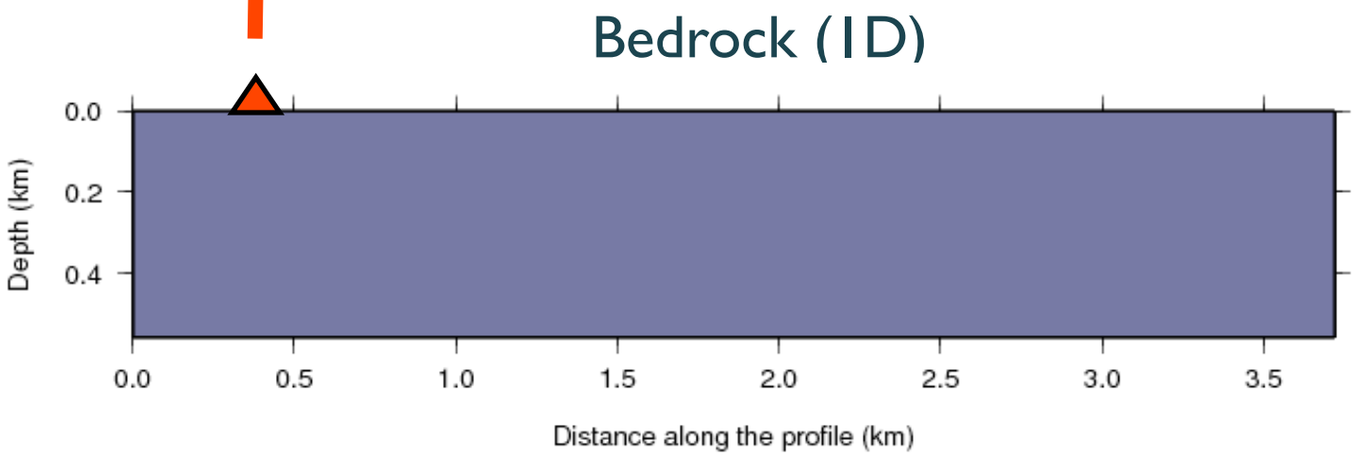
# Modelling - Spectral Amplification 2D/1D



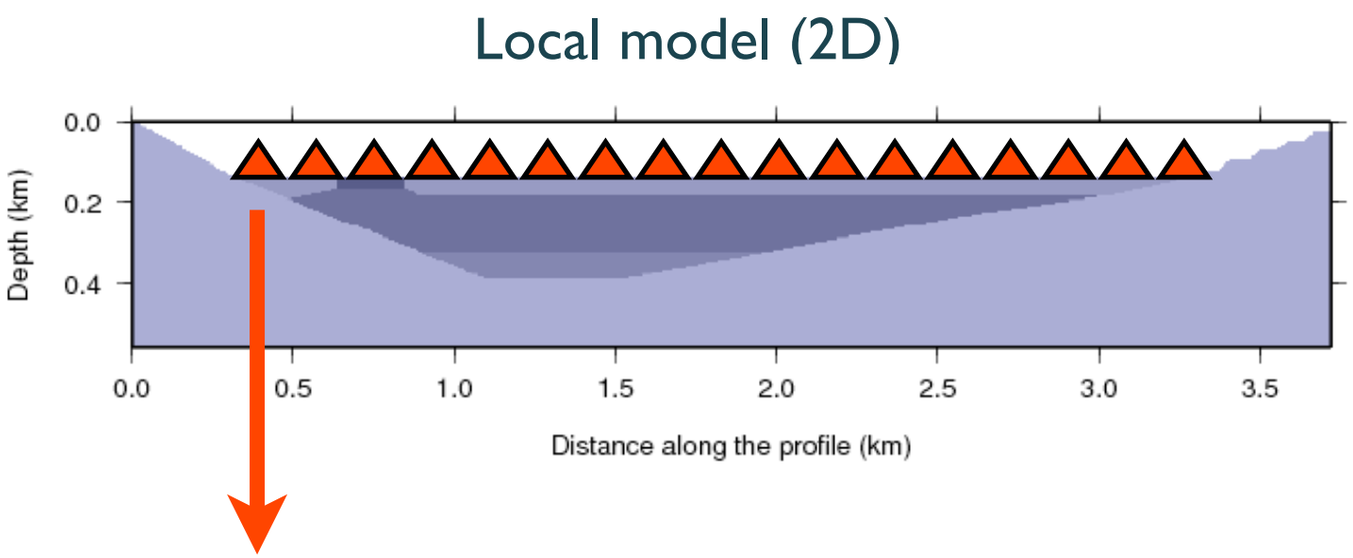

Seismogram 2D → Response spectrum 2D

Seismogram 1D → Response spectrum 1D

Response spectra ratio 2D/1D

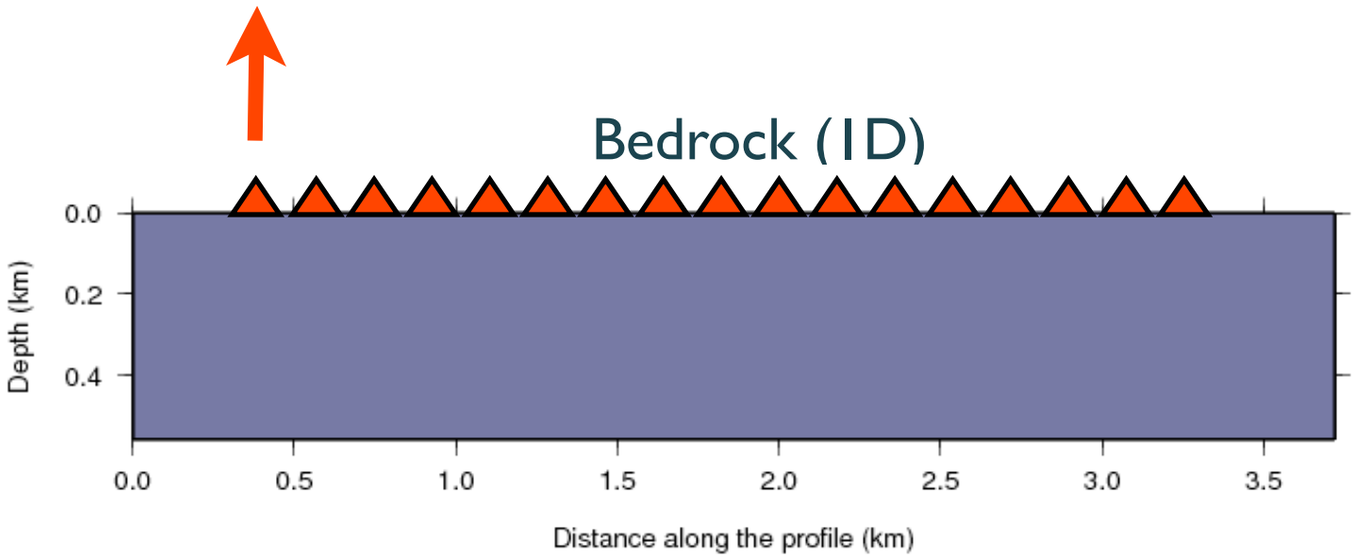


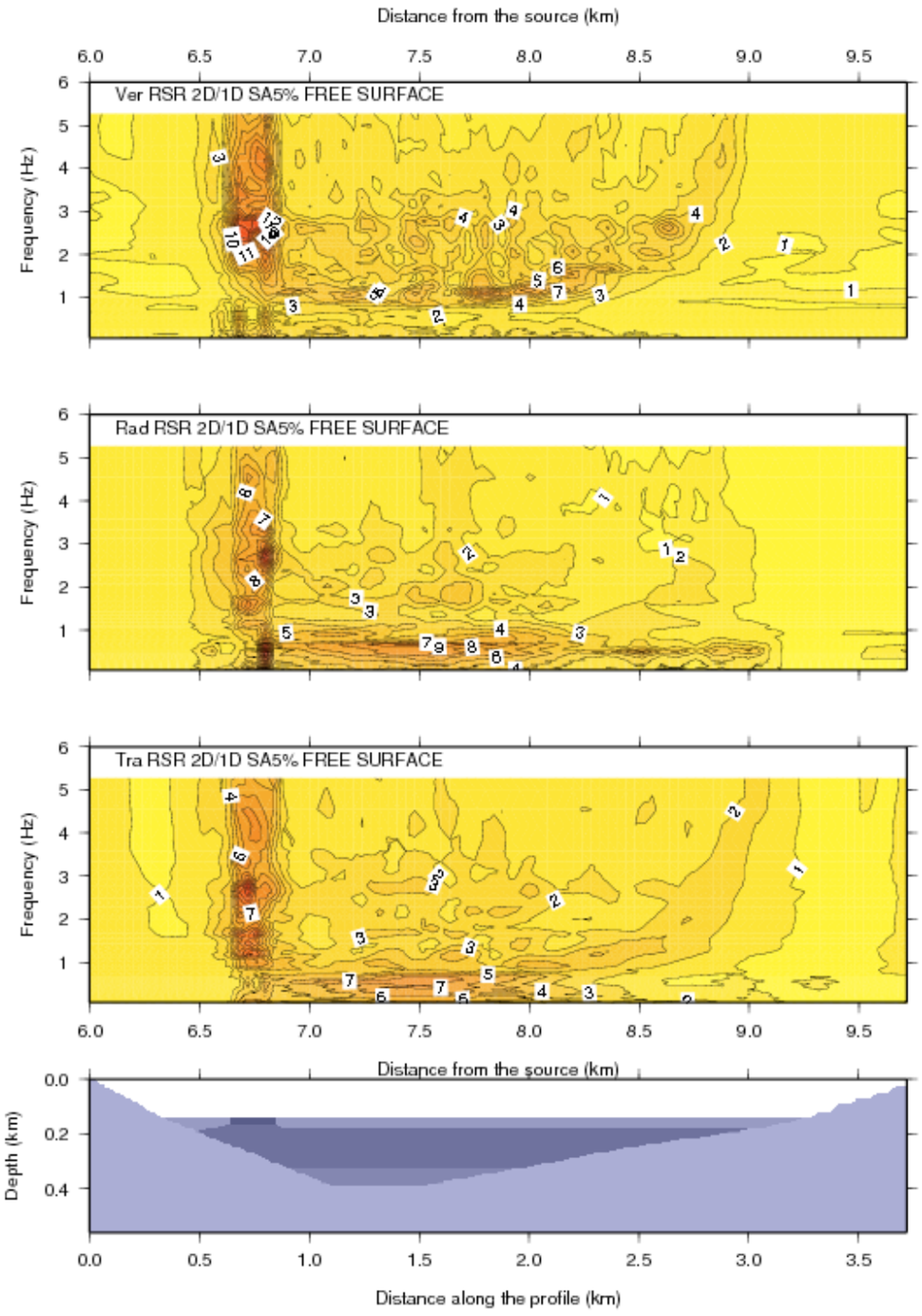
# Modelling - Spectral Amplification 2D/1D




Seismogram 2D → Response spectrum 2D

Seismogram 1D → Response spectrum 1D



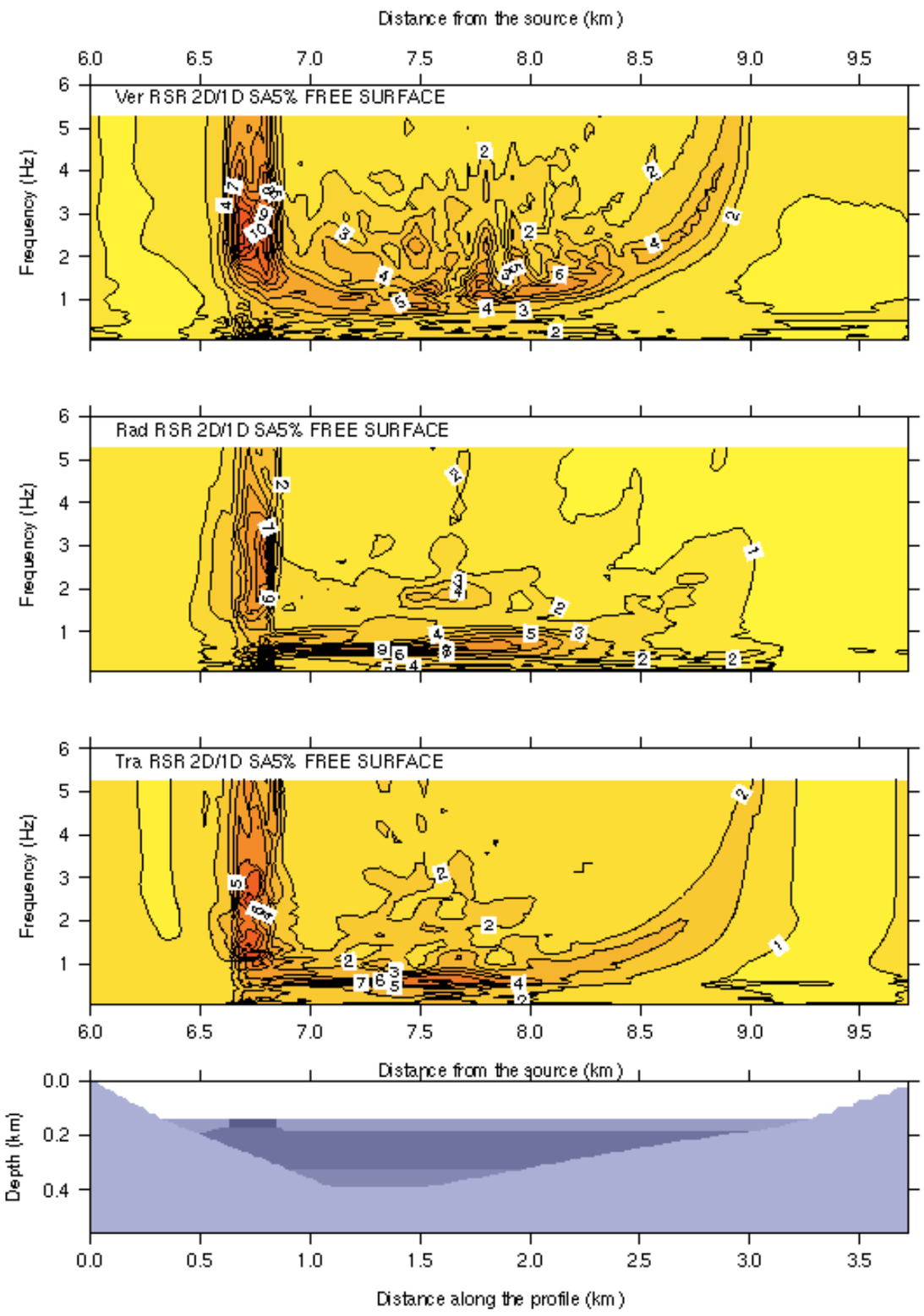



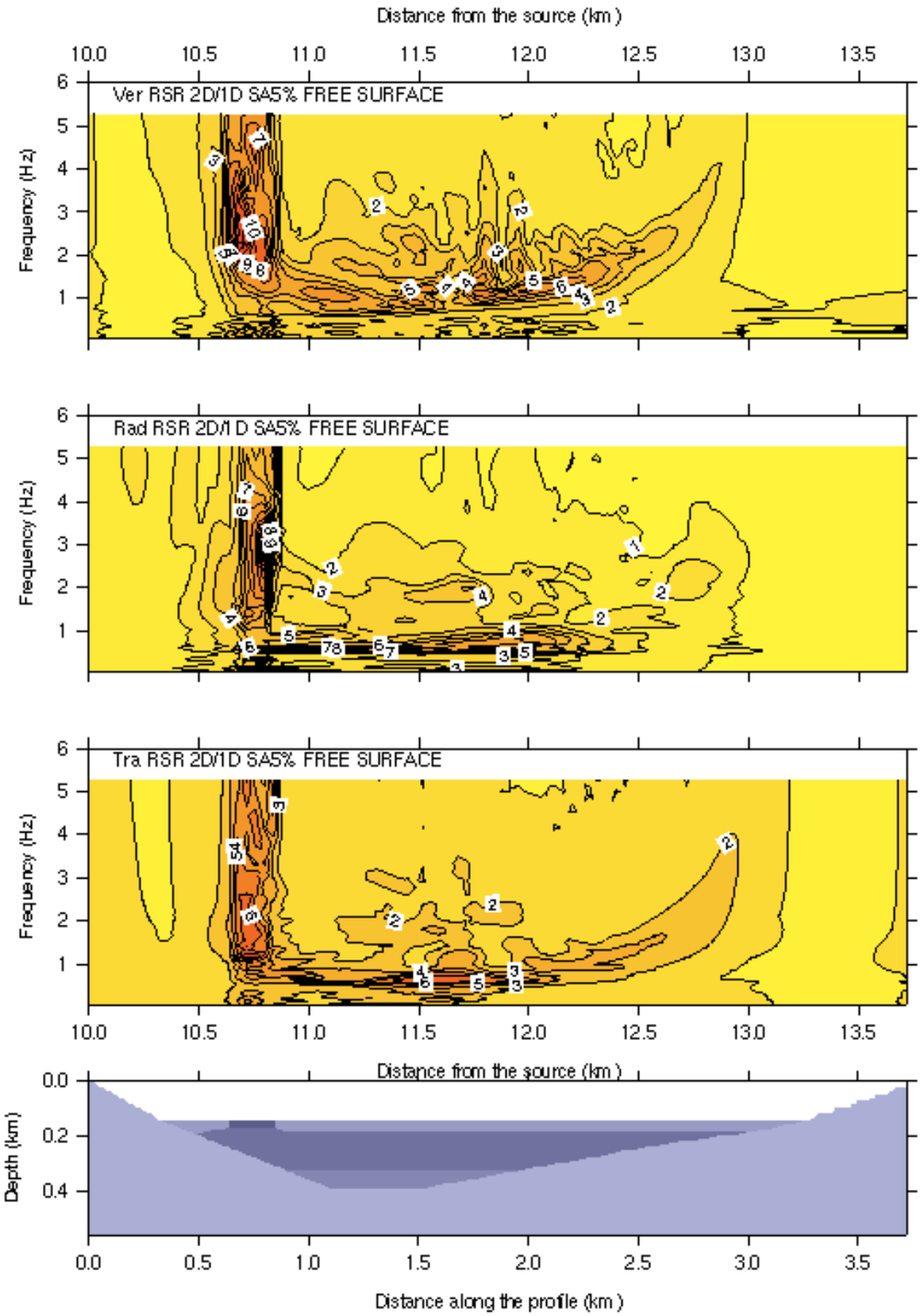
# Modelling - Parametric Tests

- Source properties (depth, distance, focal mechanism, source dimension and rupturing process)
- Bedrock properties (Vp, Vs, layer thickness)
- Local profile properties (Vp, Vs, geometry)
- Other profiles

# Parametric tests - Epicentral Distance

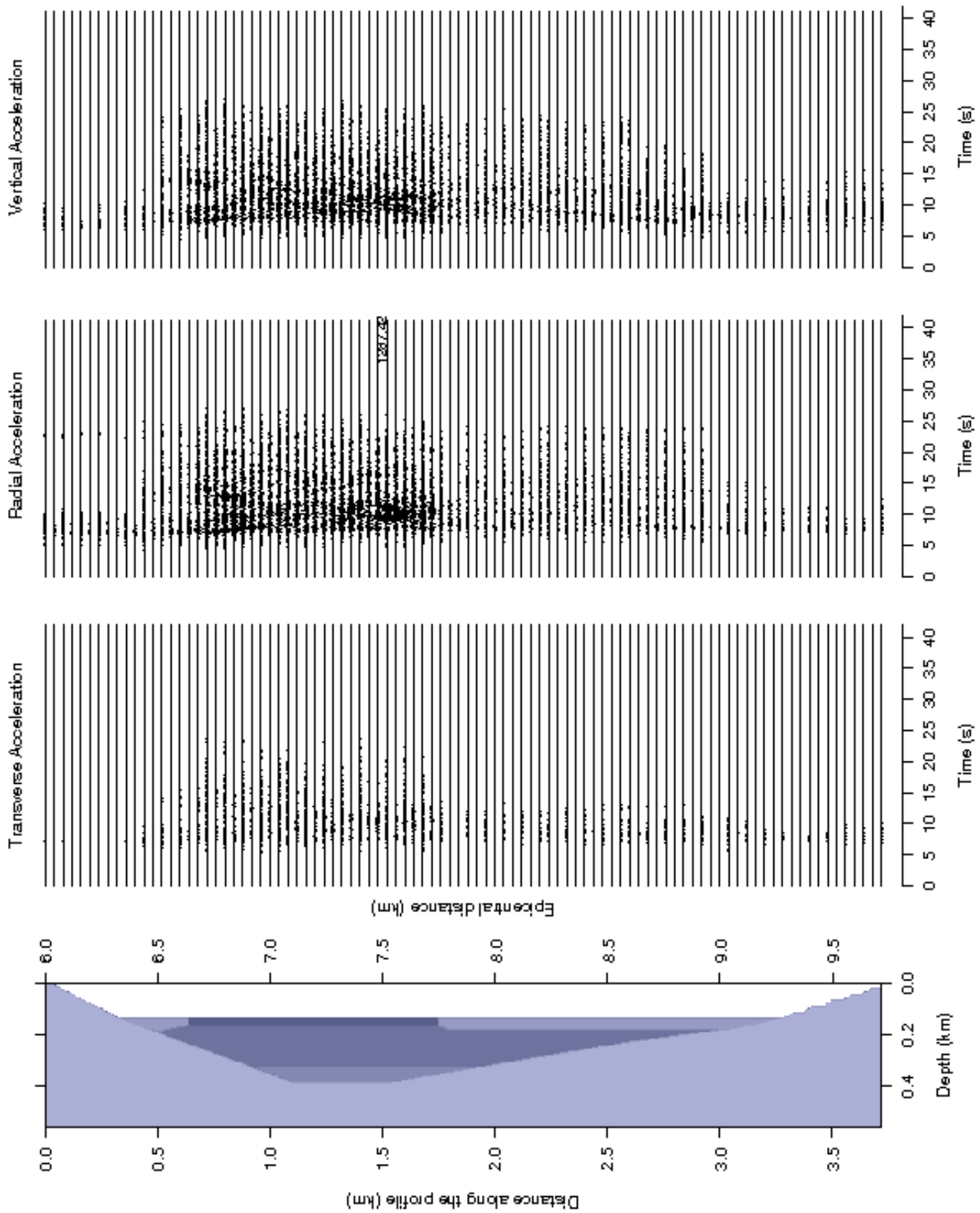
6 km — Spectral amplification 2D/1D — 10 km

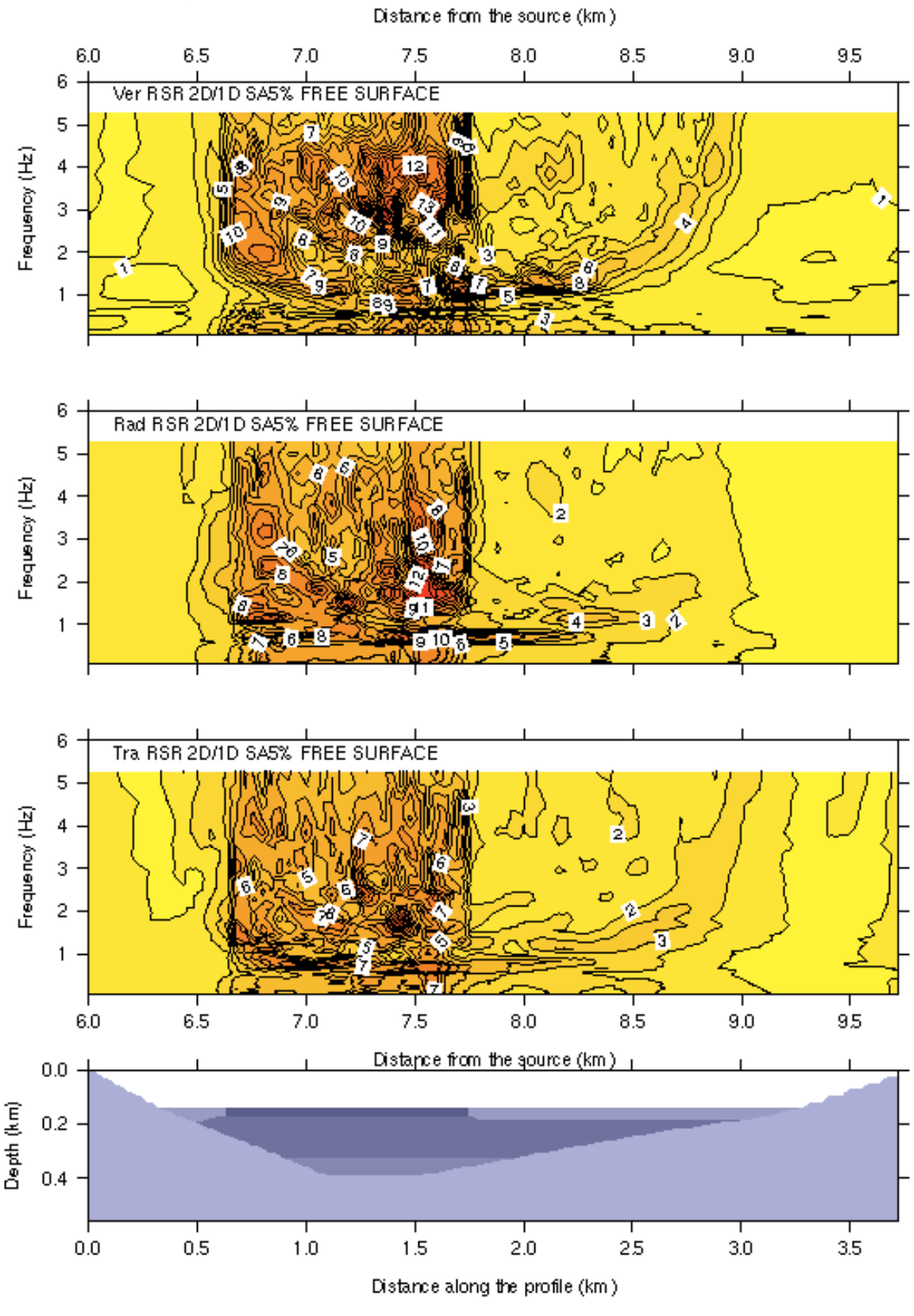


# Parametric tests - Basin Length

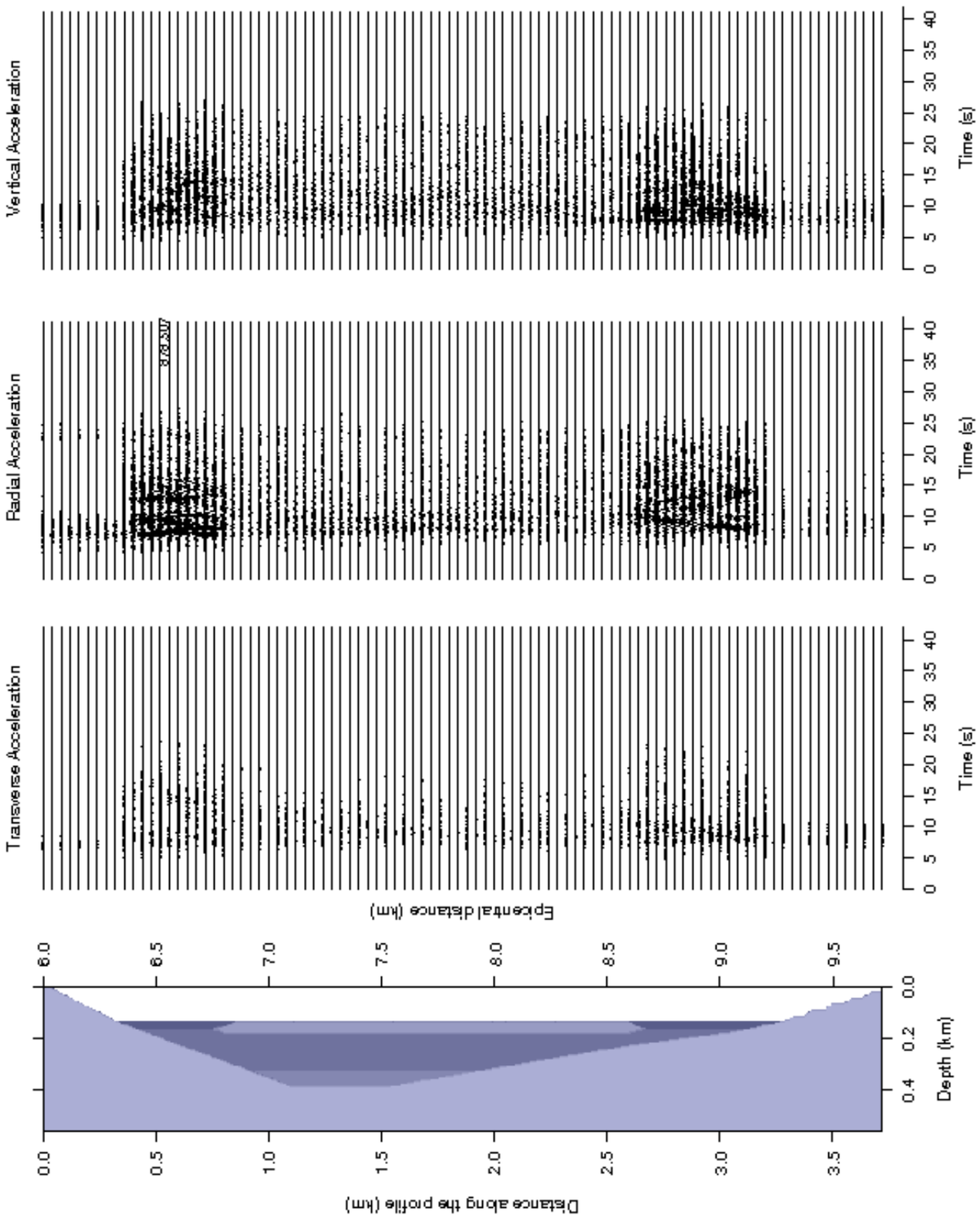
## Spectral amplification 2D/1D

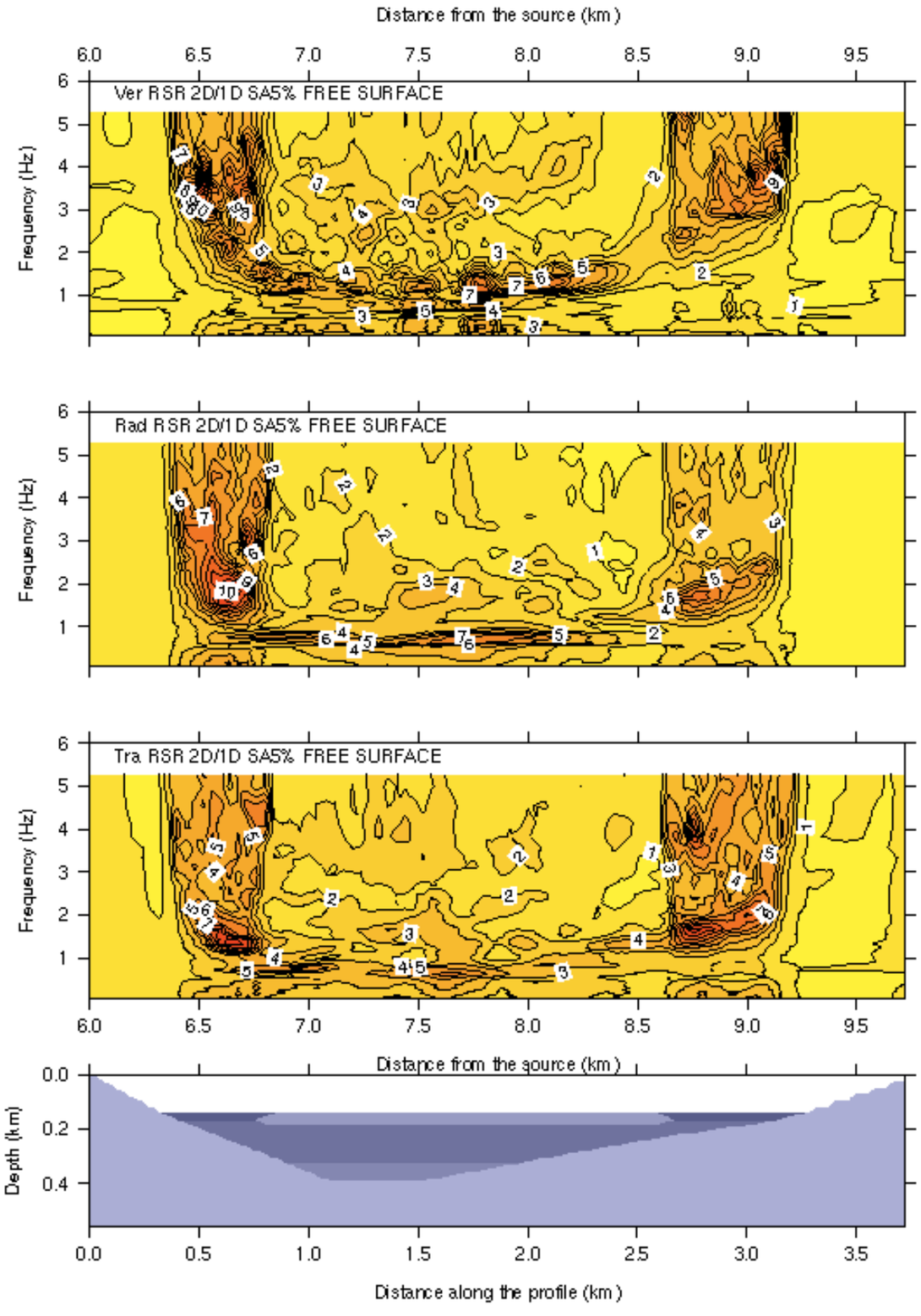


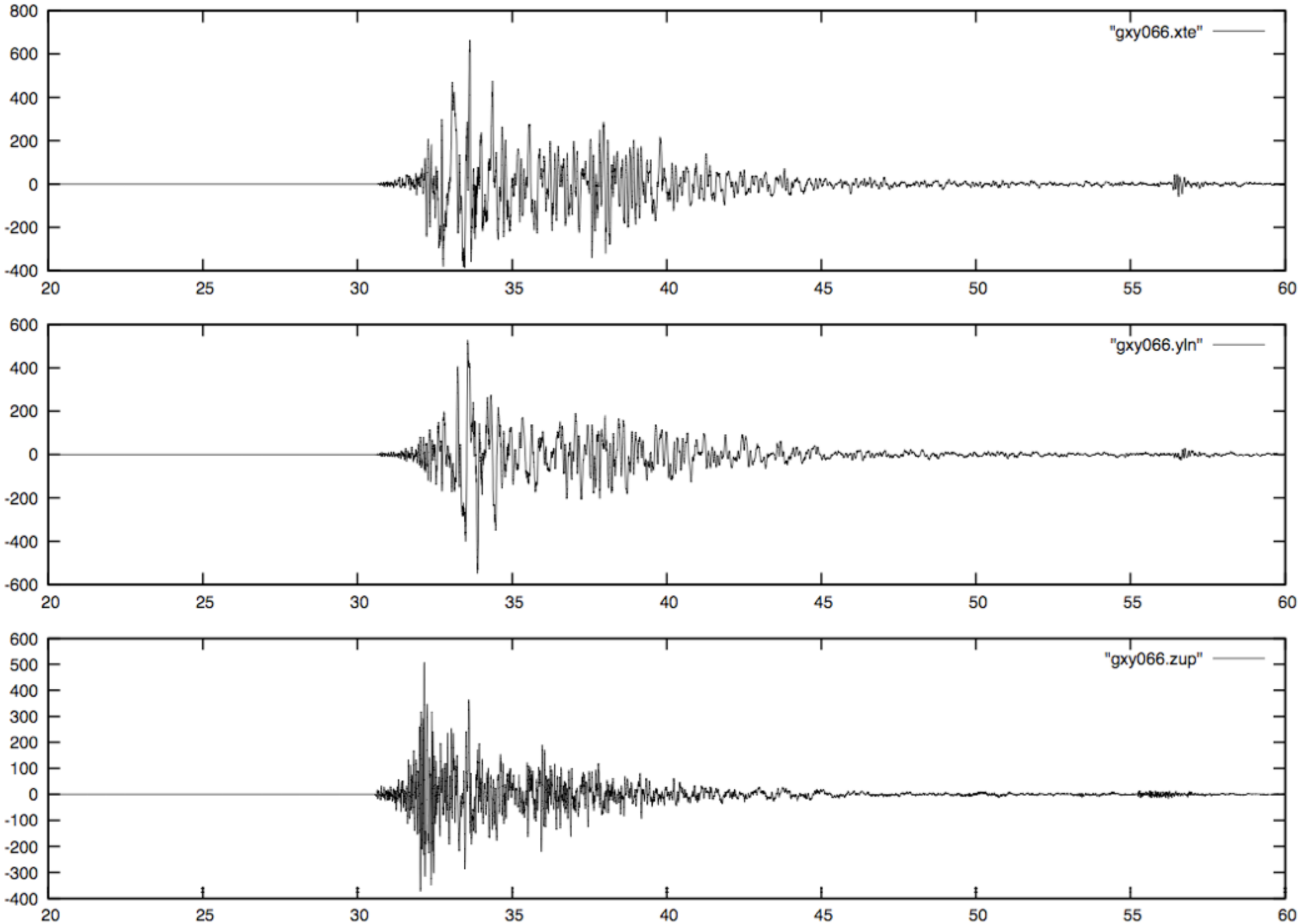
# Parametric tests - Presence of Two Basins

## Spectral amplification 2D/1D

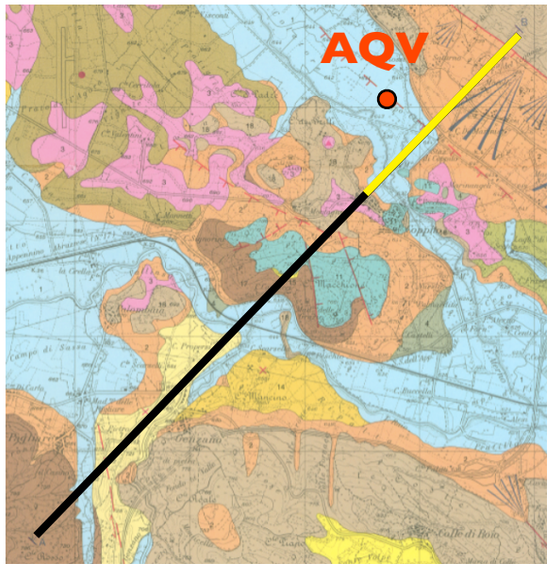


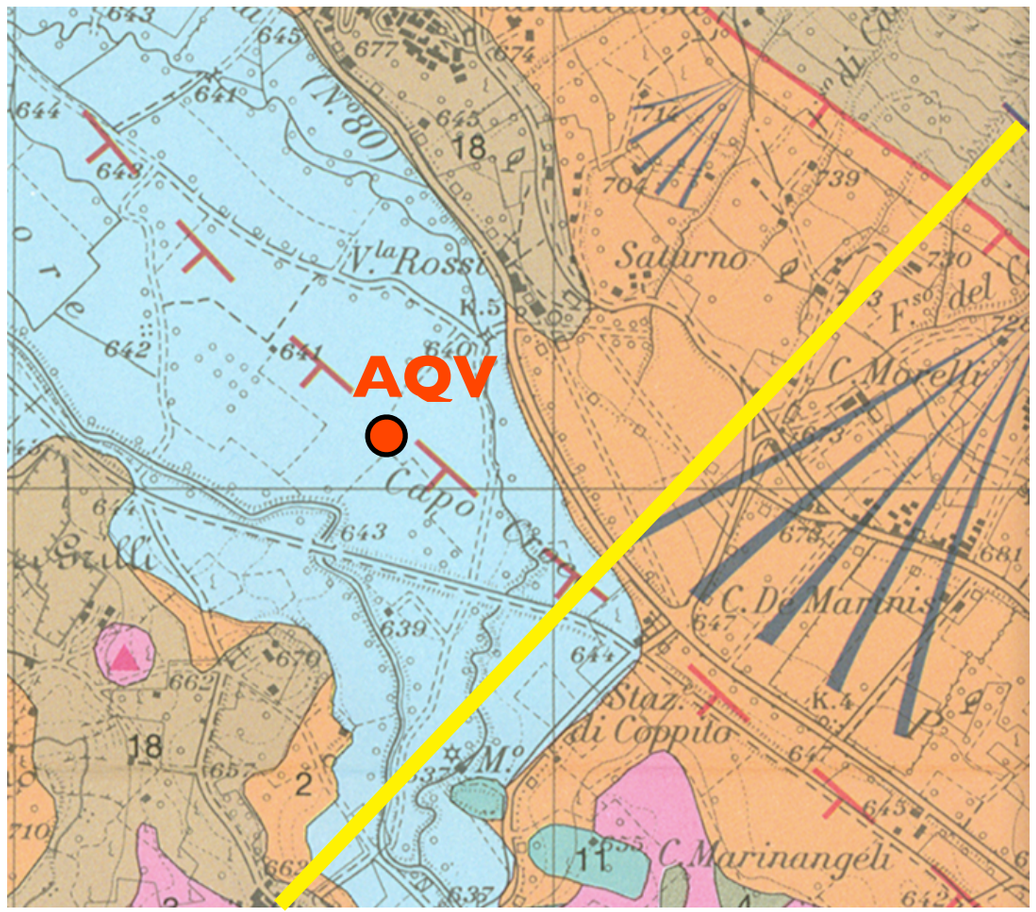



# AQV Station - Highest PGA Recorded



# AQV Station - Geologic Setting

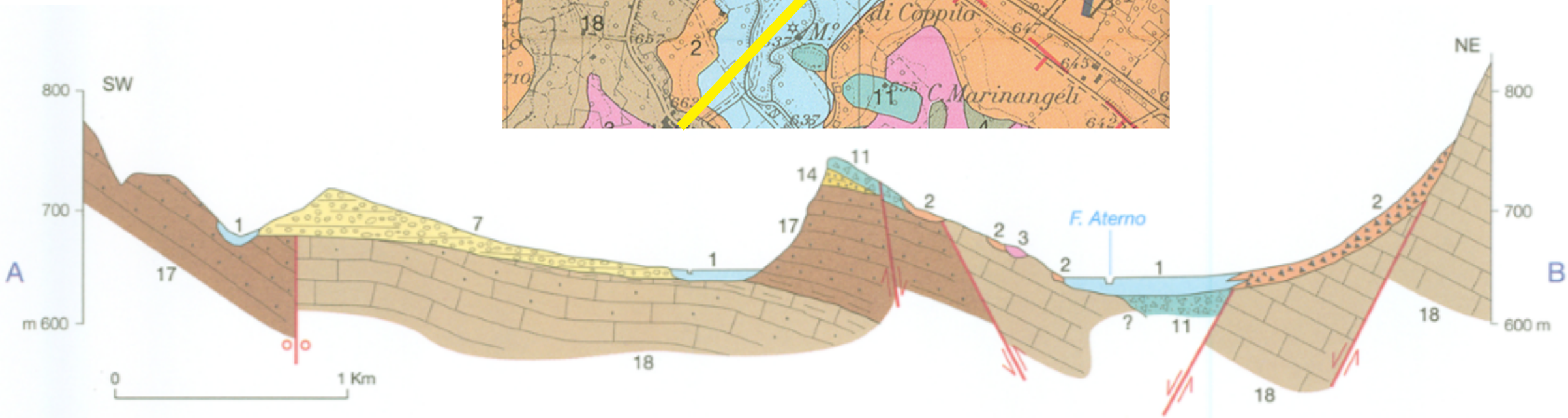


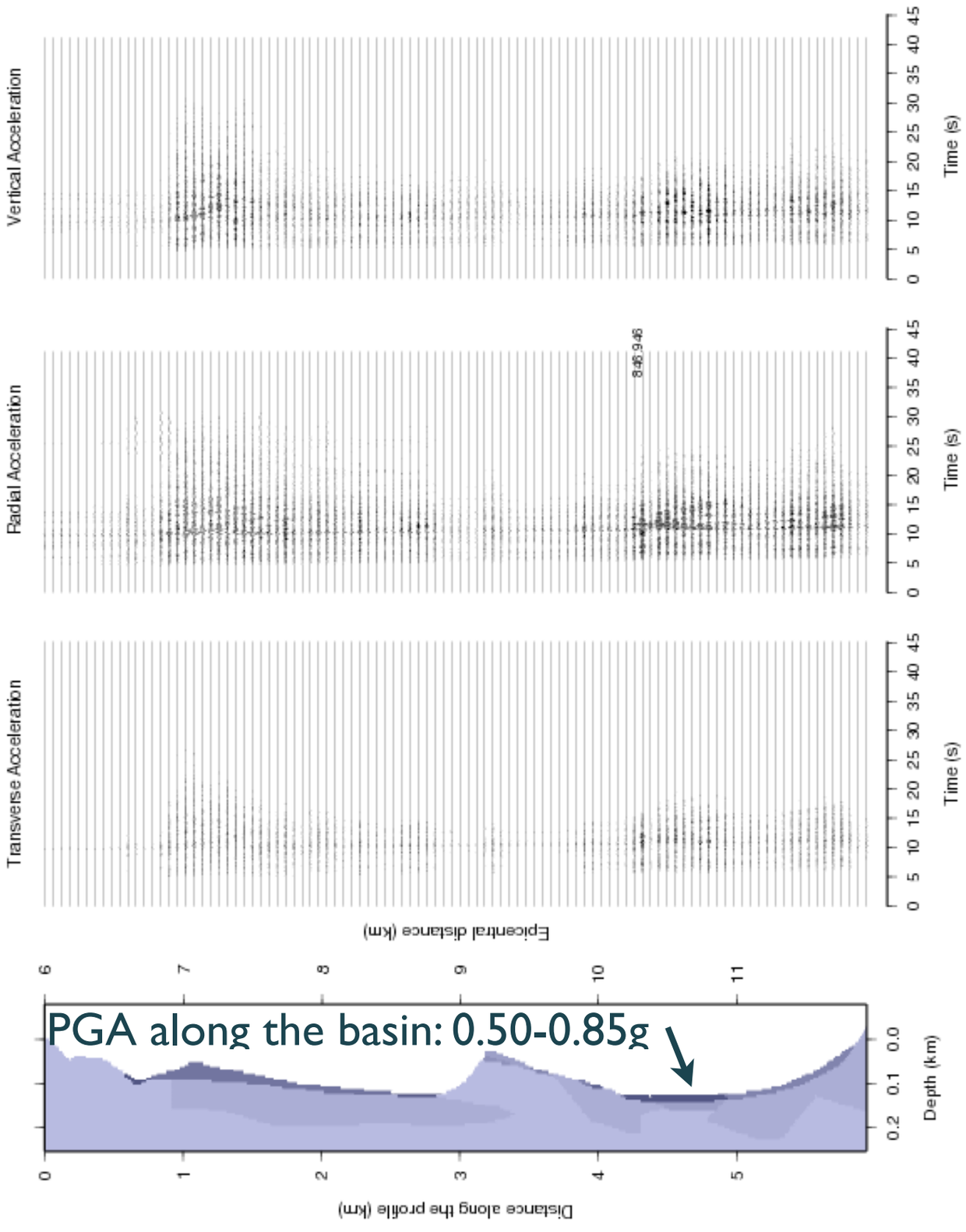

Tallini et al.,
GEAM 2002, vol 1.

SCHEMA GEO-LITOLOGICO DELLA PIANA QUATERNARIA L'AQUILA-SCOPPITO

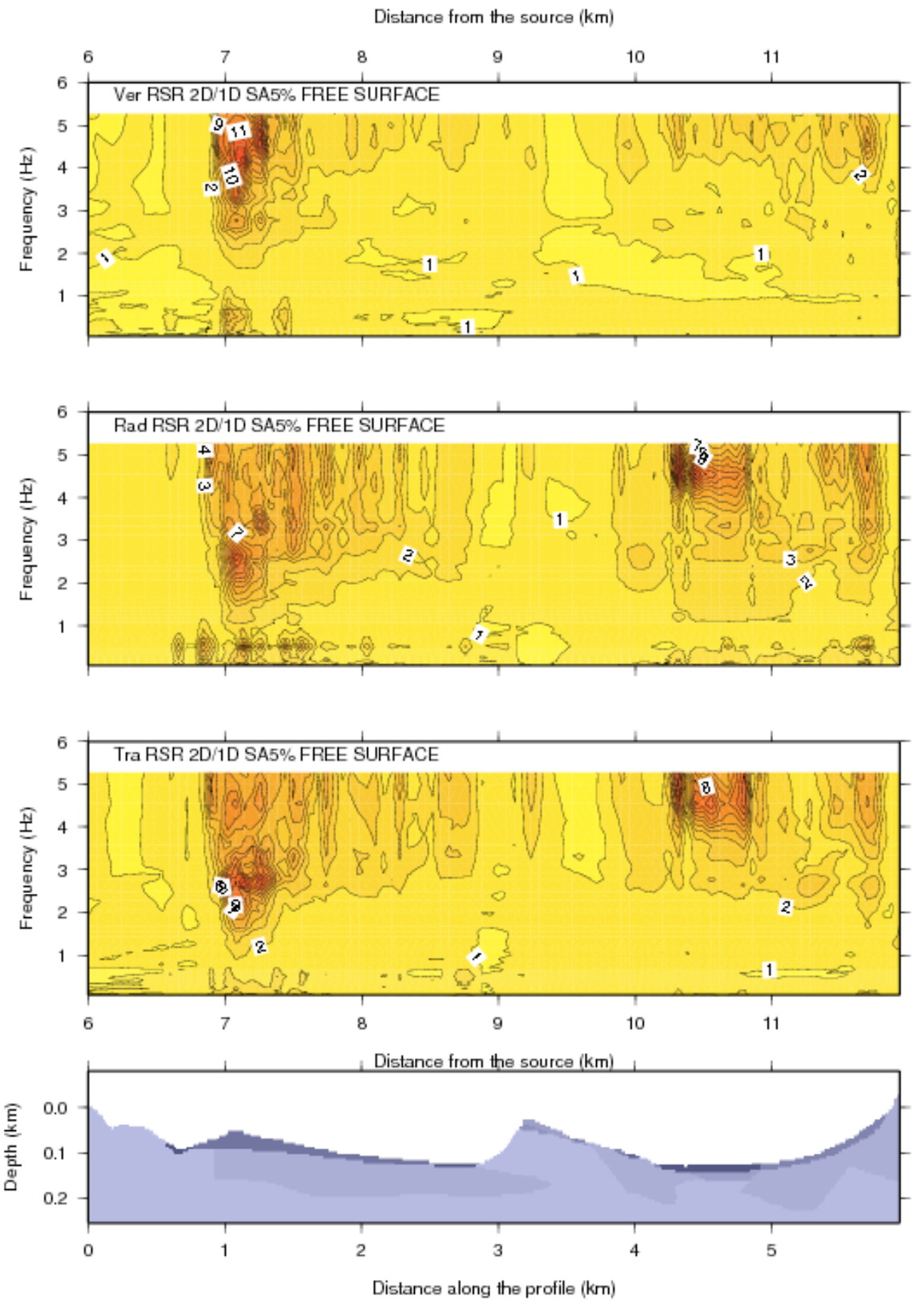
*GEO-LITHOLOGICAL MAP OF L'AQUILA-SCOPPITO QUATERNARY INTRAMONTANE PLAIN*



# AQV Station - Modelling

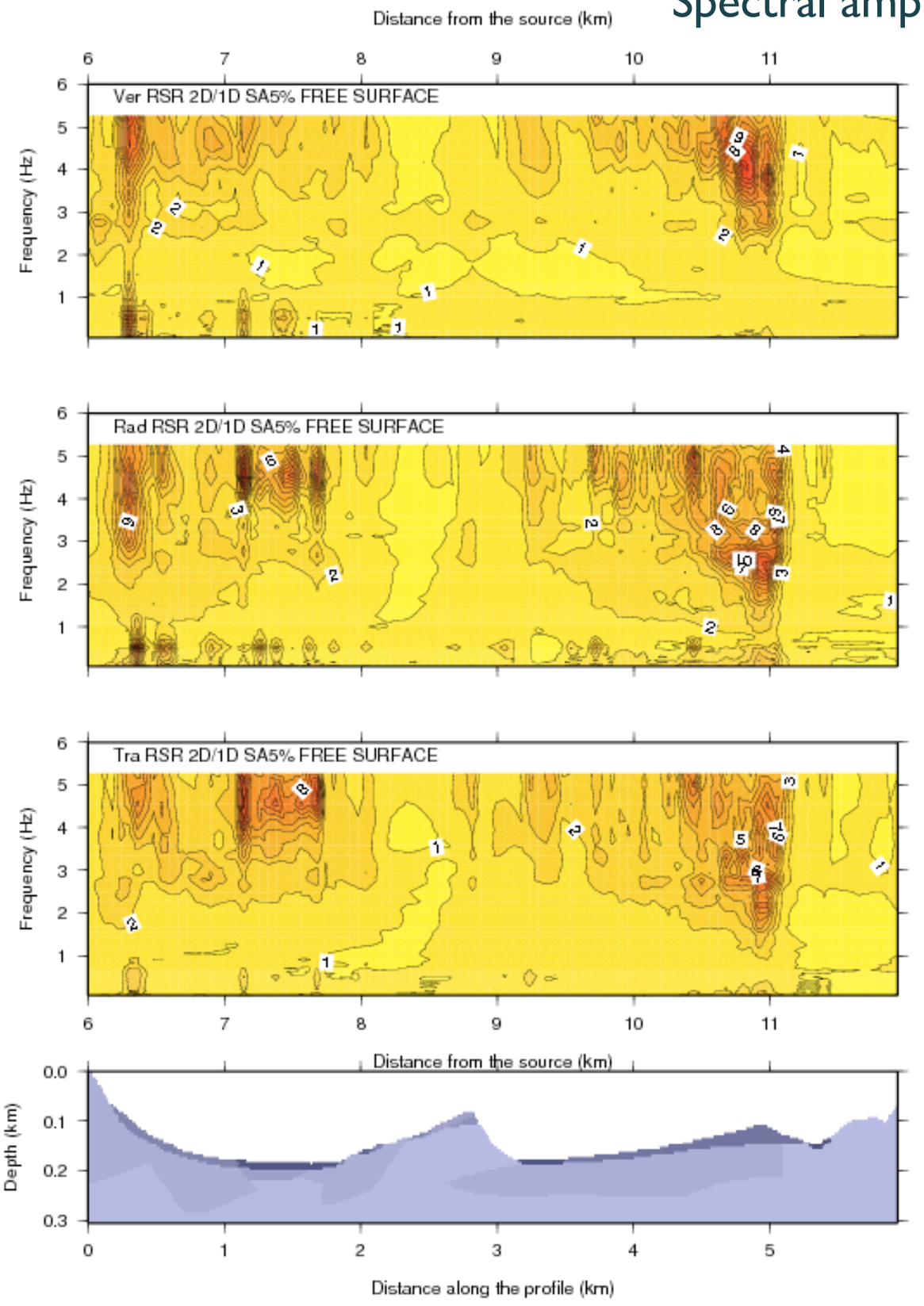


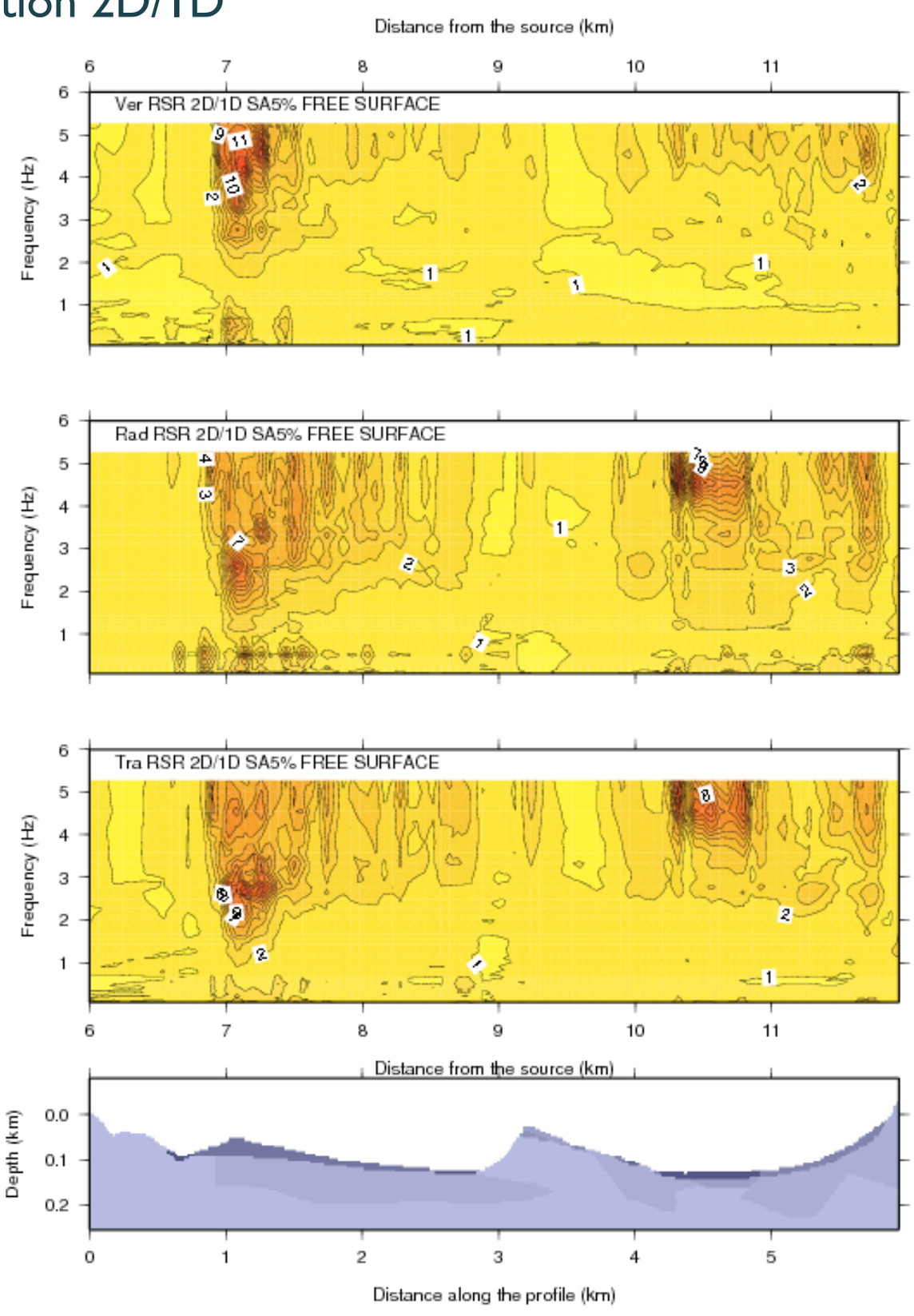

## Spectral amplification 2D/1D



# AQV Station - Test on Epicentral Position

## Spectral amplification 2D/1D



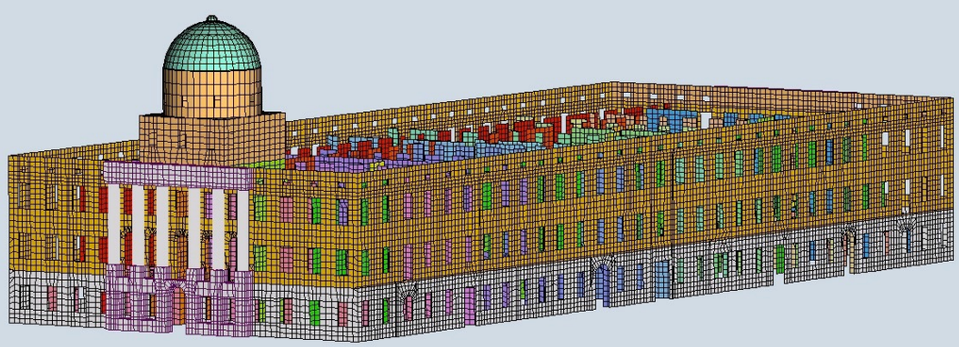



# Local Scale - Engineering Analysis

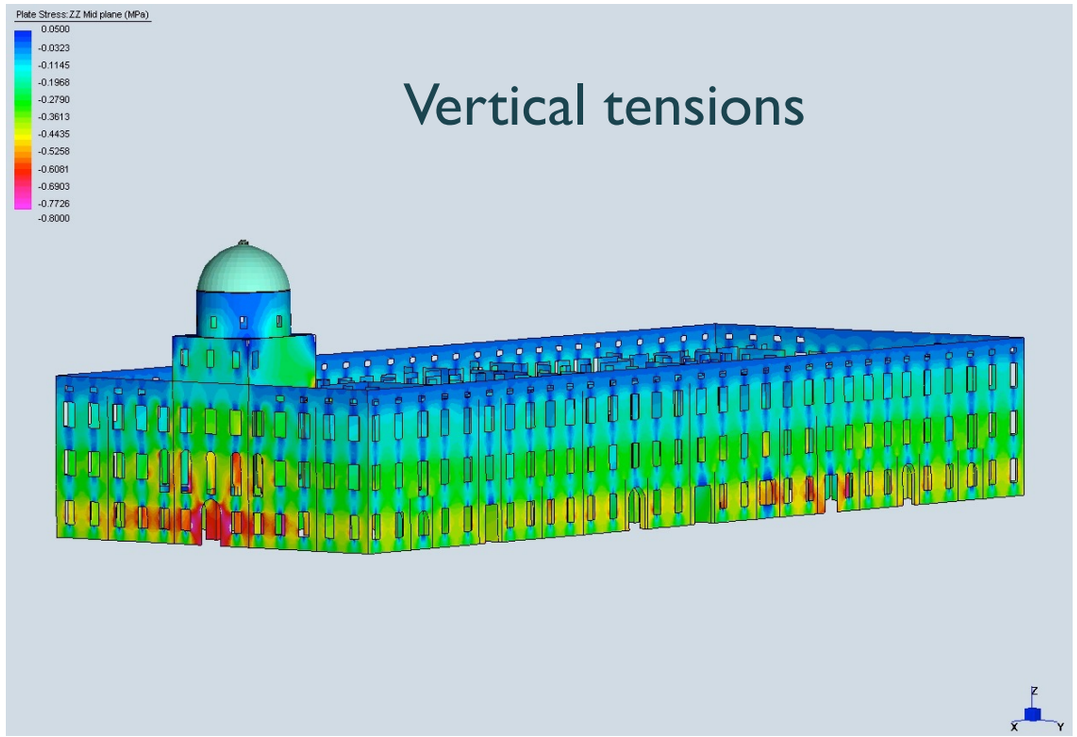
- The data set of synthetic seismograms can be used and analysed by civil engineers for design and reinforcement actions, and therefore supply a particularly powerful and economical tool for the prevention aspects of Civil Defence.
- Evaluate the response of relevant man-made structures, in terms of displacements and stresses, with respect to a set of possible scenario earthquakes

Palazzo Carciotti
(masonry)

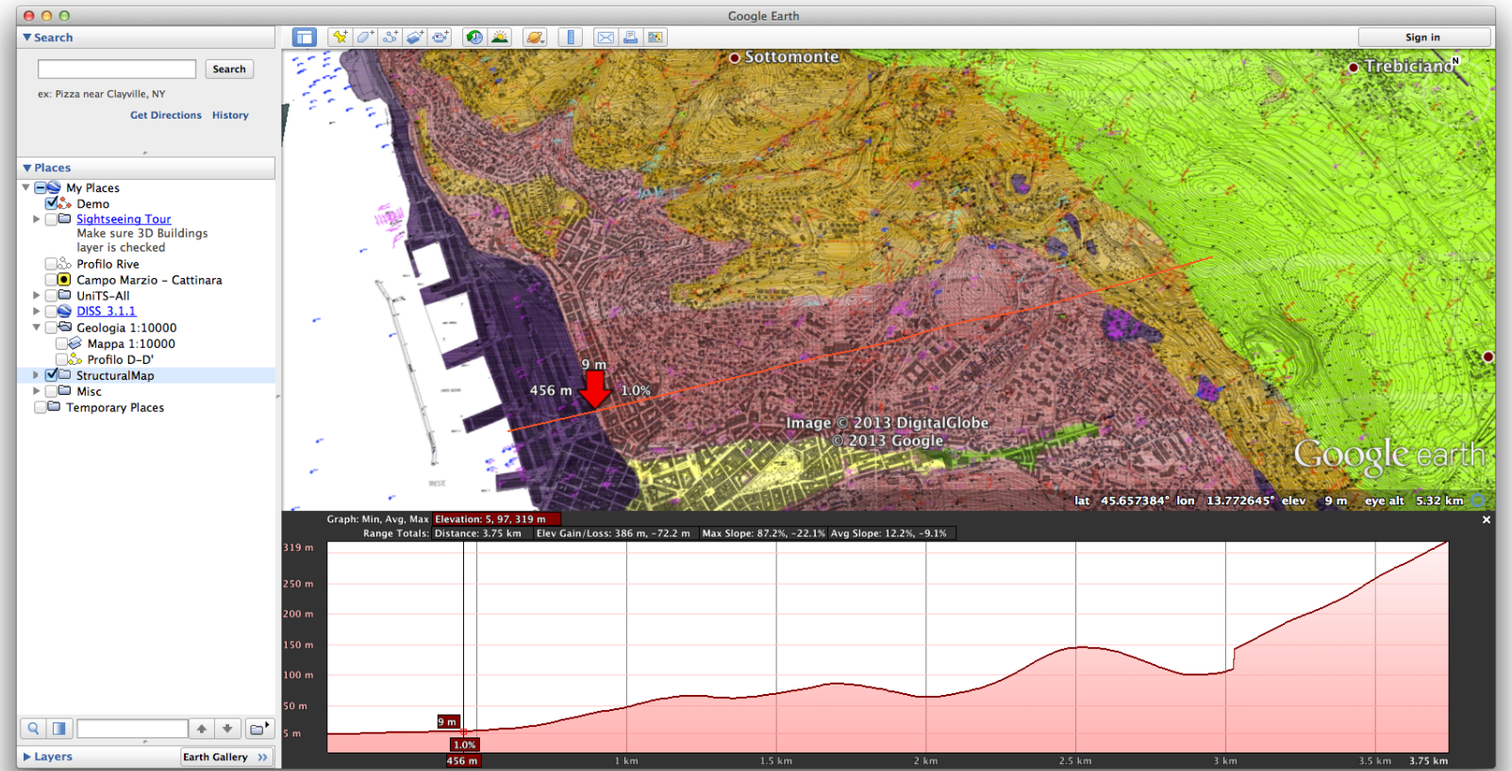

Model



Vertical tensions



# 2D profile preparation for ground motion scenario modeling




Franco Vaccari
vaccari@units.it

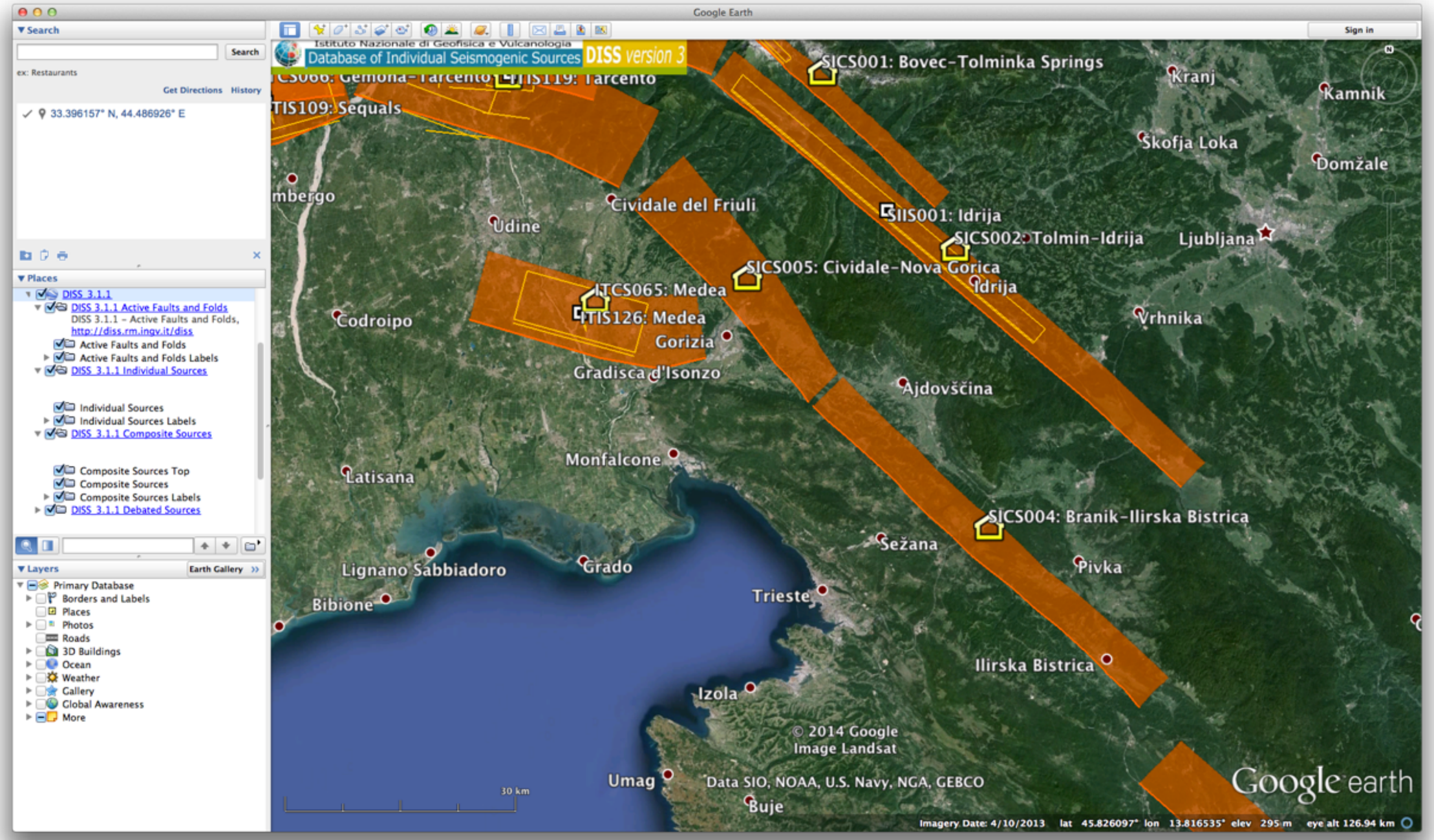
Corso di Rischio Sismico e Vulcanico - Esercitazioni

# From Google Earth to 2D profile

- Look for the potential earthquake locations by checking the Database of Individual Seismogenic Sources (http://diss.rm.ingv.it/diss/)

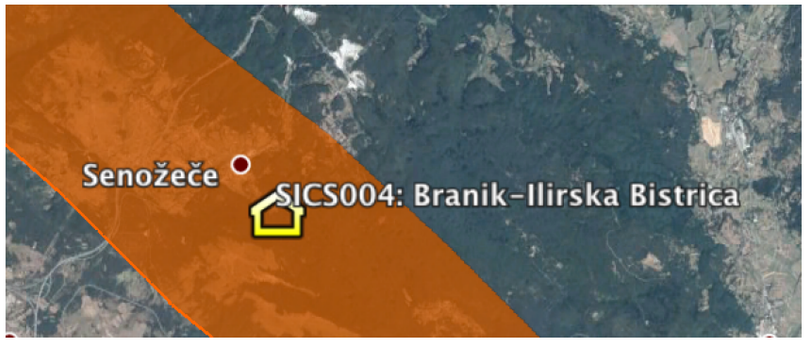
# From Google Earth to 2D profile

- Download the .kmz file and import it in Google Earth



# From Google Earth to 2D profile

## See the details about the faults




**DISS 3.1.1: Seismogenic Source SICS004 - Branik-Ilirska Bistrica**

Source Info Summary | Commentary | References | Pictures

**General information**

| | |
|---|---|
| **Code** | SICS004 |
| **Name** | Branik-Ilirska Bistrica |
| **Compiled By** | Kastelic, V., and P. Burrato |
| **Latest Update** | 29/04/2009 |

**Parametric information**

| | Parameter | Qual. | Evidence |
|---|---|---|---|
| **Min Depth (km)** | 1 | EJ | Inferred from geologic and regional structural setting. |
| **Max Depth (km)** | 12 | EJ | Inferred from geologic and regional structural setting. |
| **Strike (deg)** | 300 - 325 | LD | Based on geologic and geomorphological maps and data. |
| **Dip (deg)** | 70 - 85 | LD | Based on geologic, structural and seismological data. |
| **Rake (deg)** | 160 - 180 | EJ | Inferred from geological and seismological data. |
| **Slip Rate (mm/y)** | 0.1 - 0.5 | EJ | Calculated from geodetic and geodynamic data. |
| **Max Magnitude (Mw)** | 5.5 | EJ | Assumed from regional seismological data. |

**Q-keys:** LD = Literature Data; OD = Original Data; ER = Empirical Relationship; AR = Analytical Relationship; EJ = Expert Judgement

**DISS 3.1.1: Seismogenic Source SICS004 - Branik-Ilirska Bistrica**

Source Info Summary | Commentary | References | Pictures

COMMENTS

The domain of active strike-slip deformation in NW and W Slovenia is positioned between the S vergent thrust domain in the Friuli area of NE Italy and SW thrusting domain of the Dinarides. Earthquake and geology data in NE Italy indicate that the prevailing mechanism of deformation is thrusting on E-W oriented planes whereas dextral-reverse and purely dextral strike-slip displacements on NNW-SSE oriented planes occur further E and SE. The prevailing fault orientation in the Dinarides is in the orogen-parallel NW-SE direction. Earthquakes and geologic data along these faults exhibit thrust focal mechanisms in the southern and central parts of the Dinarides, and dextral-reverse mechanisms in the northern Dinarides.

**DISS 3.1.1: Seismogenic Source SICS004 - Branik-Ilirska Bistrica**

Source Info Summary | Commentary | References | Pictures

**Number of pictures: 4**

| Picture | Title |
|---|---|
| Figure 01 | - Geological map of central western Slovenia |
| Figure 02 | - Map of focal mechanism solutions for the Southern Alps |
| Figure 03 | - Recorded historical and instrumental seismicity for the region of NE Italy and W Slovenia |
| Figure 04 | - Regional cross-sections |

**DISS 3.1.1: Seismogenic Source SICS004 - Branik-Ilirska Bistrica**

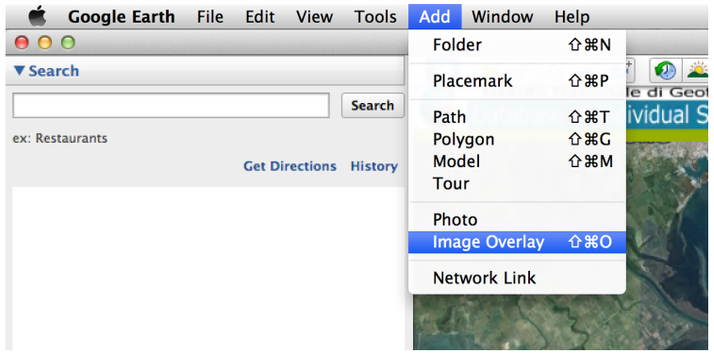
Source Info Summary | Commentary | References | Pictures

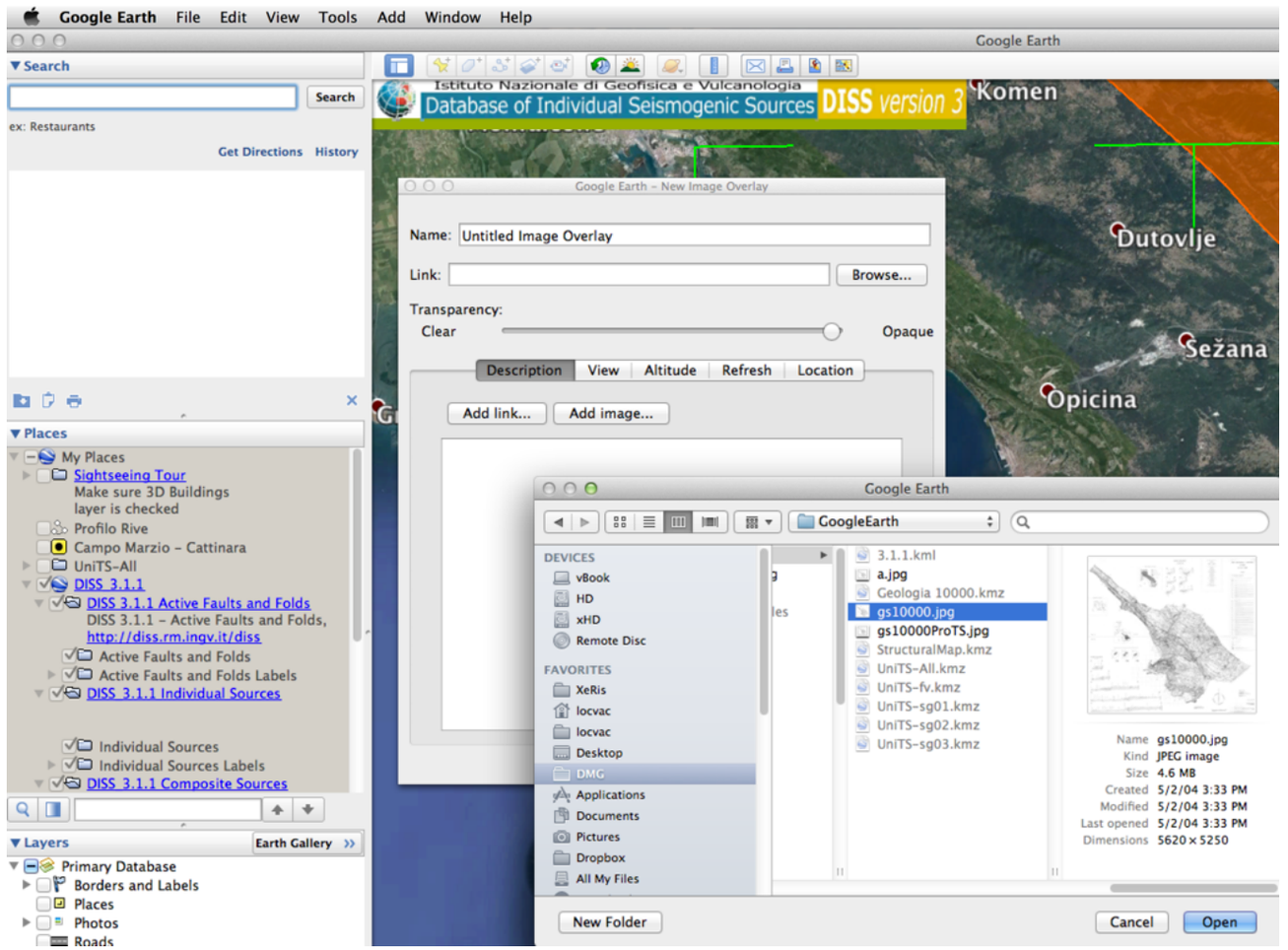
**Number of references: 21**

| Author | Year | Title | Reference |
|---|---|---|---|
| Bechtold, M., M. Battaglia, D. C. Tanner and D. Zuliani | 2009 | Constraints on the active tectonics of the Friuli/NW Slovenia area from CGPS measurements and three-dimensional kinematic modeling. | J. Geophys. Res., 114, B03408, 10.1029/2008JB005638. |
| Boschi, E., E. Guidoboni, G. Ferrari, D. Mariotti, G. Valensise and P. Gasperini | 2000 | Catalogue of Strong Italian Earthquakes, 461 b.C to 1997. | Ann. Geofis., 43, 609-868, with database on CD-ROM. |
| Bruckl, E., F. Bleibinhaus, A. Gosar, M. Grad, A. Guterch, P. Hrubcova, G.R. Keller, M. Majdanski, F. Sumanovac, T. Tiira, J. Yliniemi, E. Hegedus and H. Thybo | 2007 | Crustal structure due to collisional and escape tectonics in the Eastern Alps region based on profiles Alp01 and Alp02 from the ALP 2002 seismic experiment. | J. Geophys. Res., 112, B06308, 10.1029/2006JB004687. |
| Brückl, E., M. Behm, K. Decker, M. Grad, A. Guterch, G. R. Keller and H. Thybo | 2010 | Crustal structure and active tectonics in the Eastern Alps. | Tectonics, 29, TC2011, 10.1029/2009TC002491. |

# From Google Earth to 2D profile

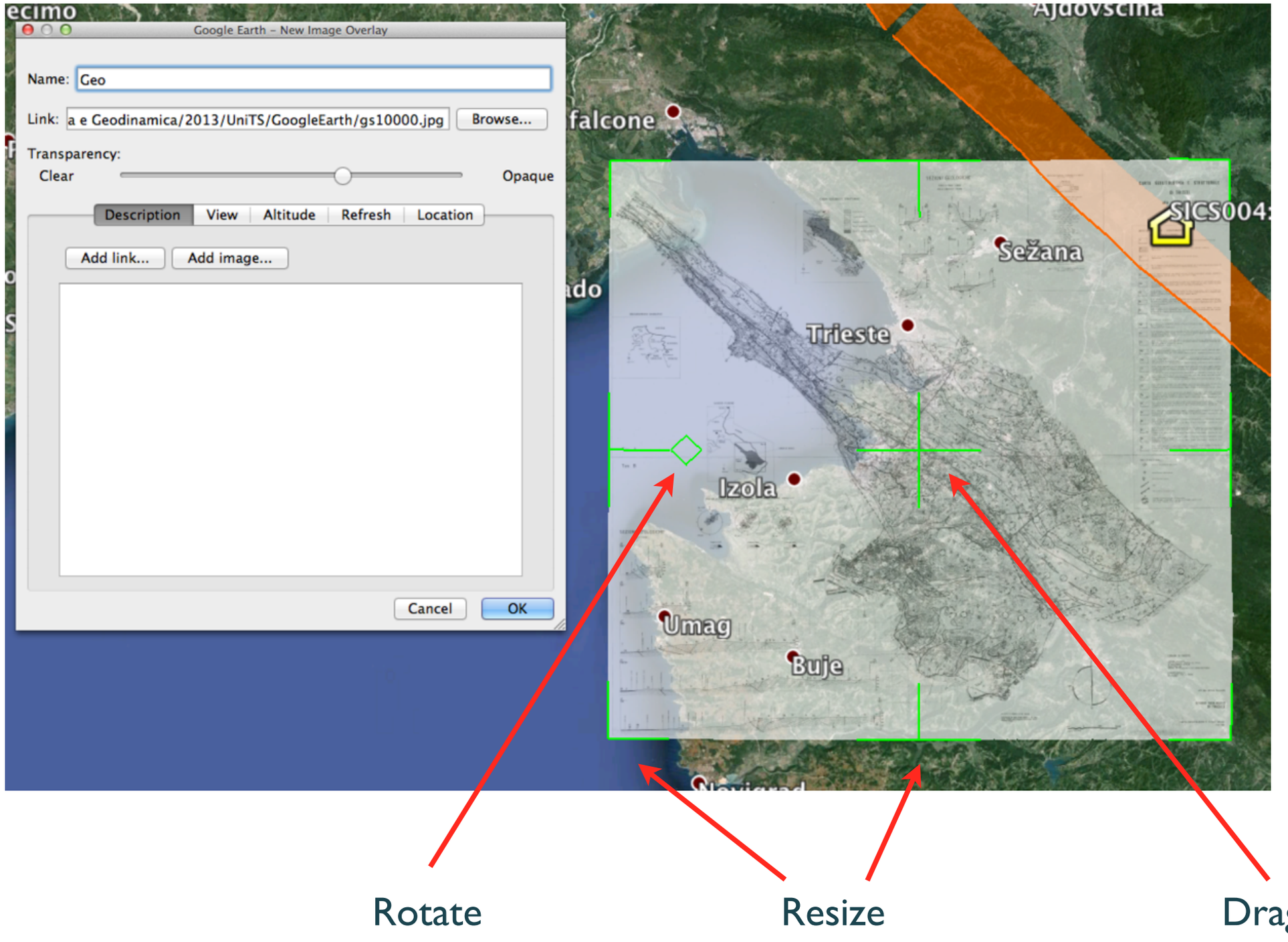
## Import a geological map



# From Google Earth to 2D profile

- Adjust its opacity and make it fit with the terrain view

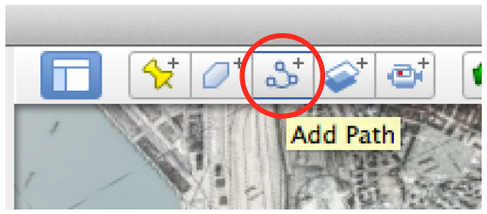


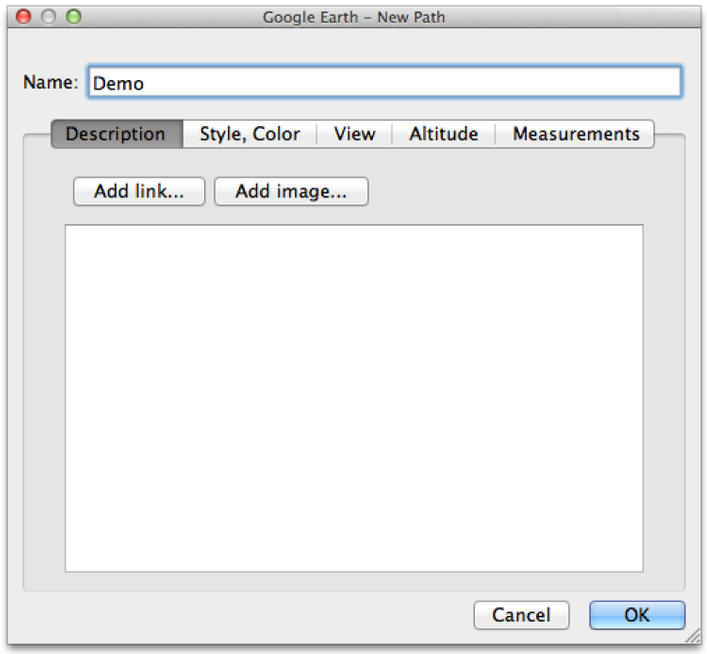
# From Google Earth to 2D profile

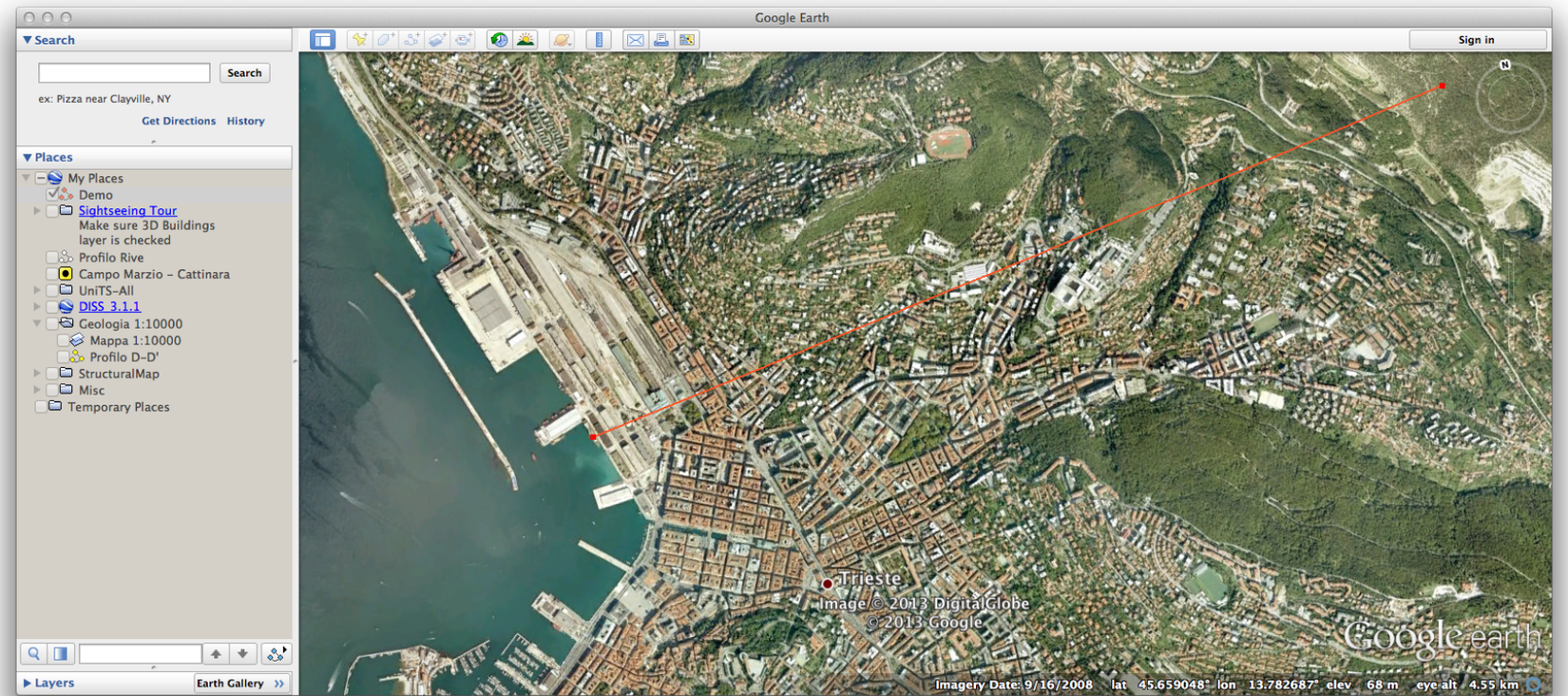
- Main keyboard shortcuts in Google Earth
  - N (North) — orient the view to the North
  - U (Up) — view from above
  - arrows — pan the map
  - shift-arrows — rotate/tilt the map

# From Google Earth to 2D profile

## Trace the profile

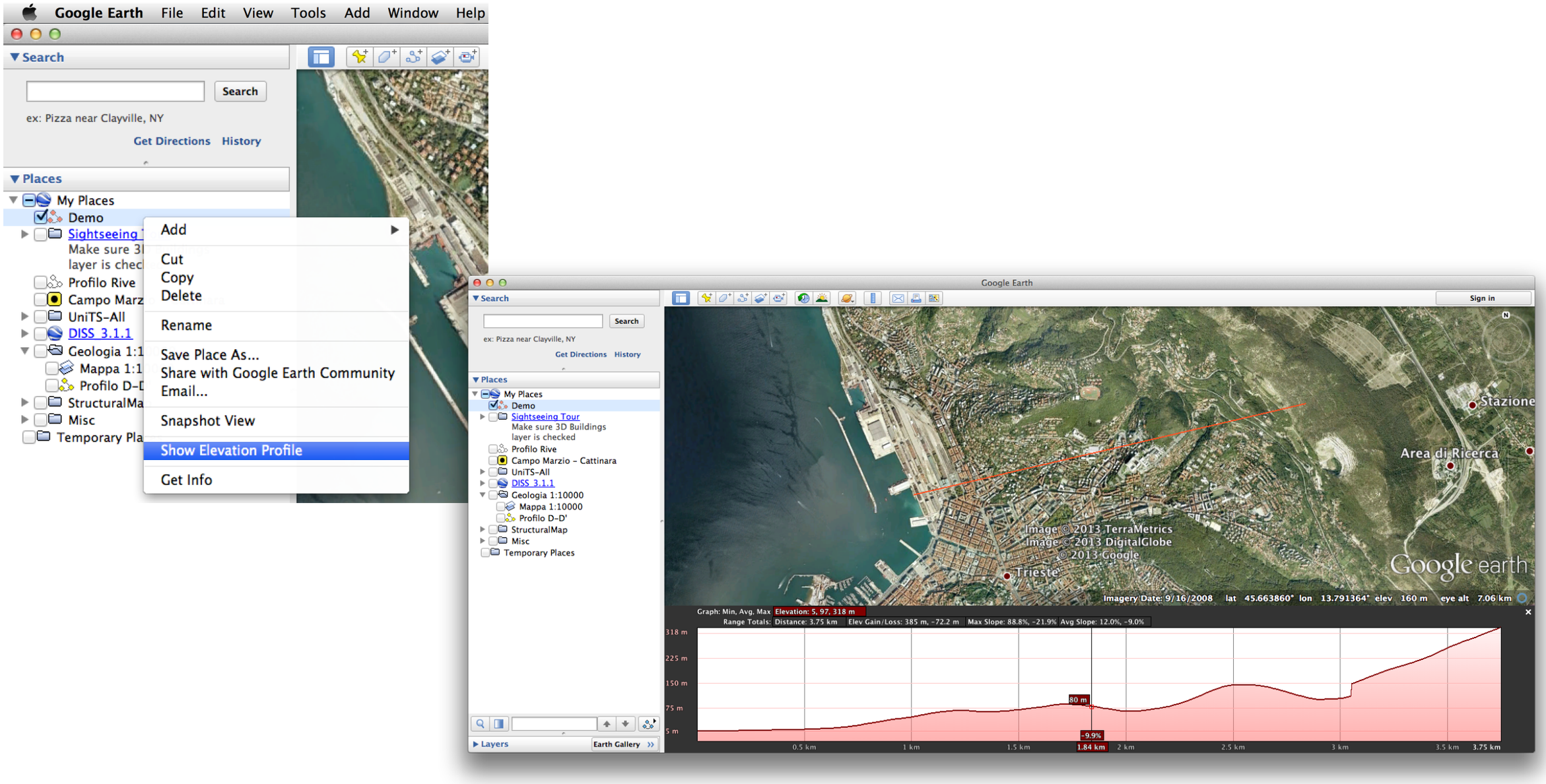


# From Google Earth to 2D profile

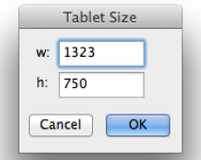
## Get the elevation profile

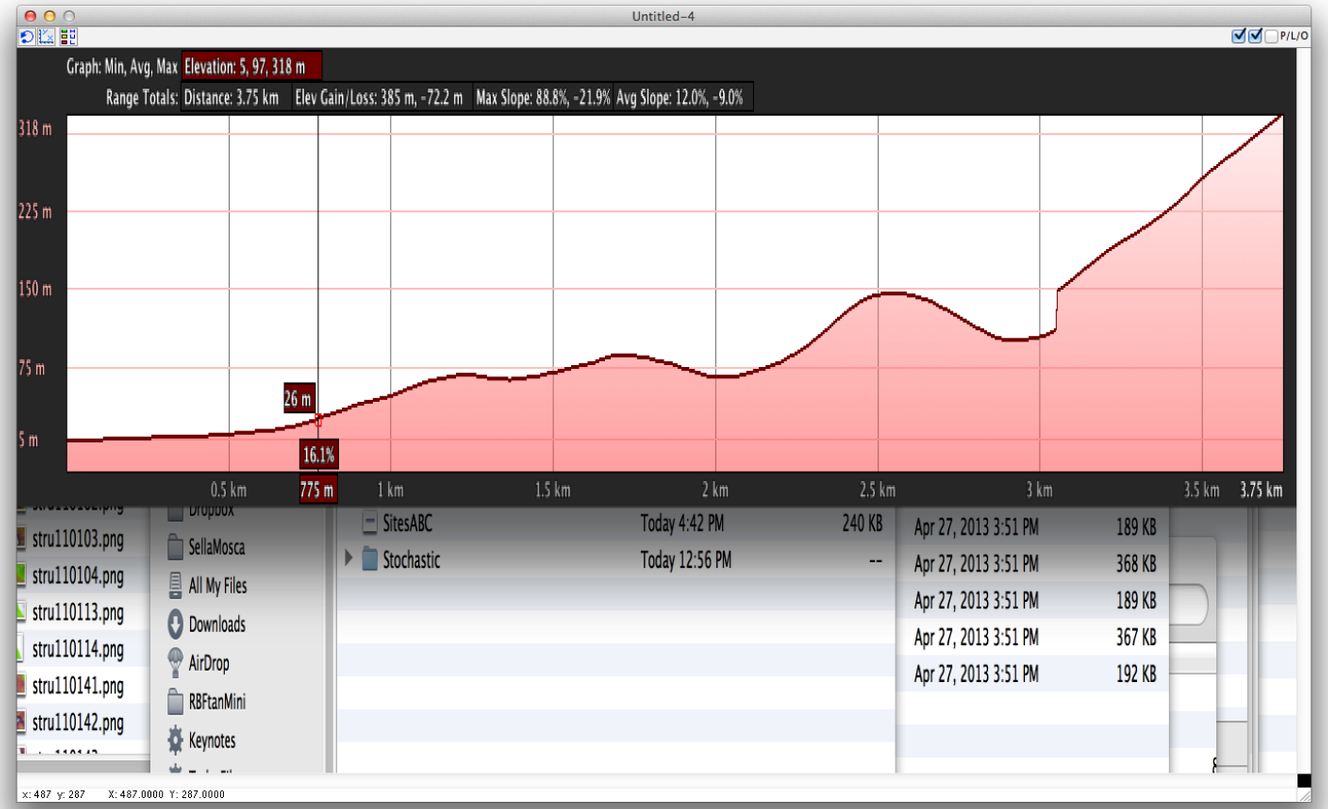



## Check for possible errors, to be later corrected in XDigiMac

# From Google Earth to 2D profile

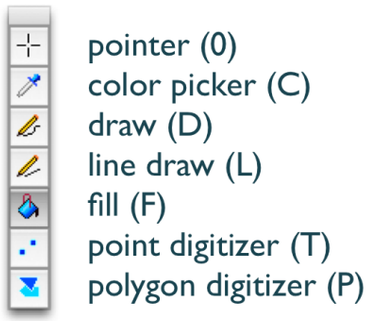
- Get a screenshot of the elevation profile (cmd-ctrl-shift-4)
- Launch XDigiMac
- Create a new tablet (cmd-N)
- Adjust the proposed tablet size if necessary
- Paste the screenshot into the Tablet

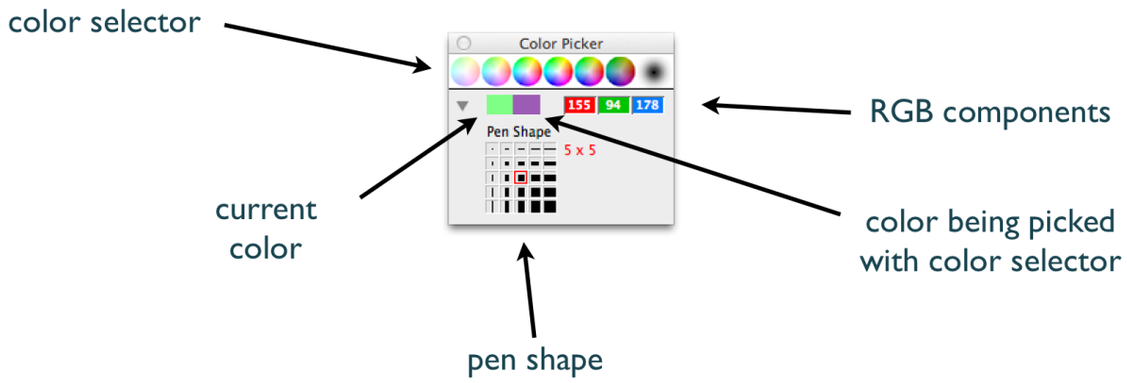


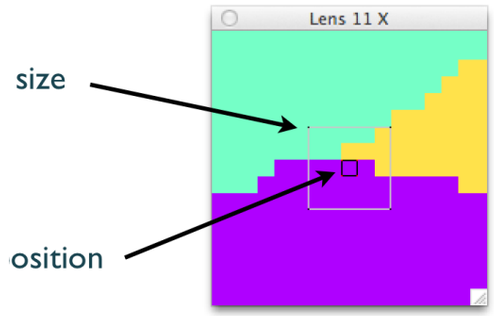



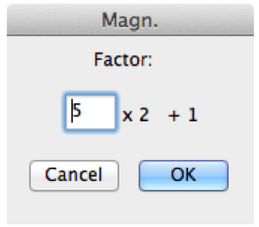
# From Google Earth to 2D profile

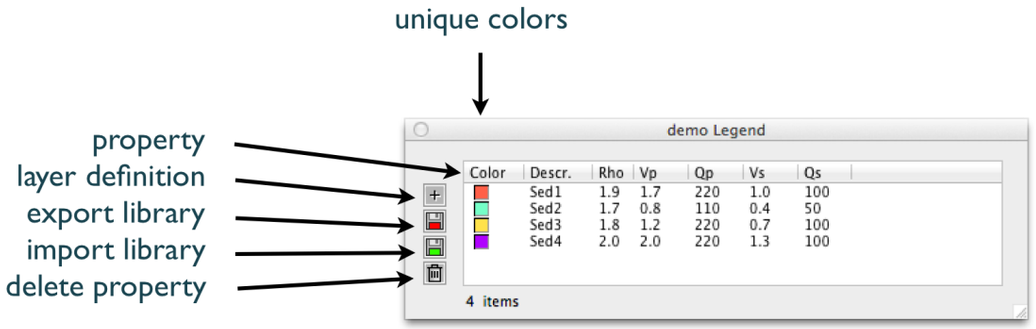
## Main elements of XDigiMac user interface

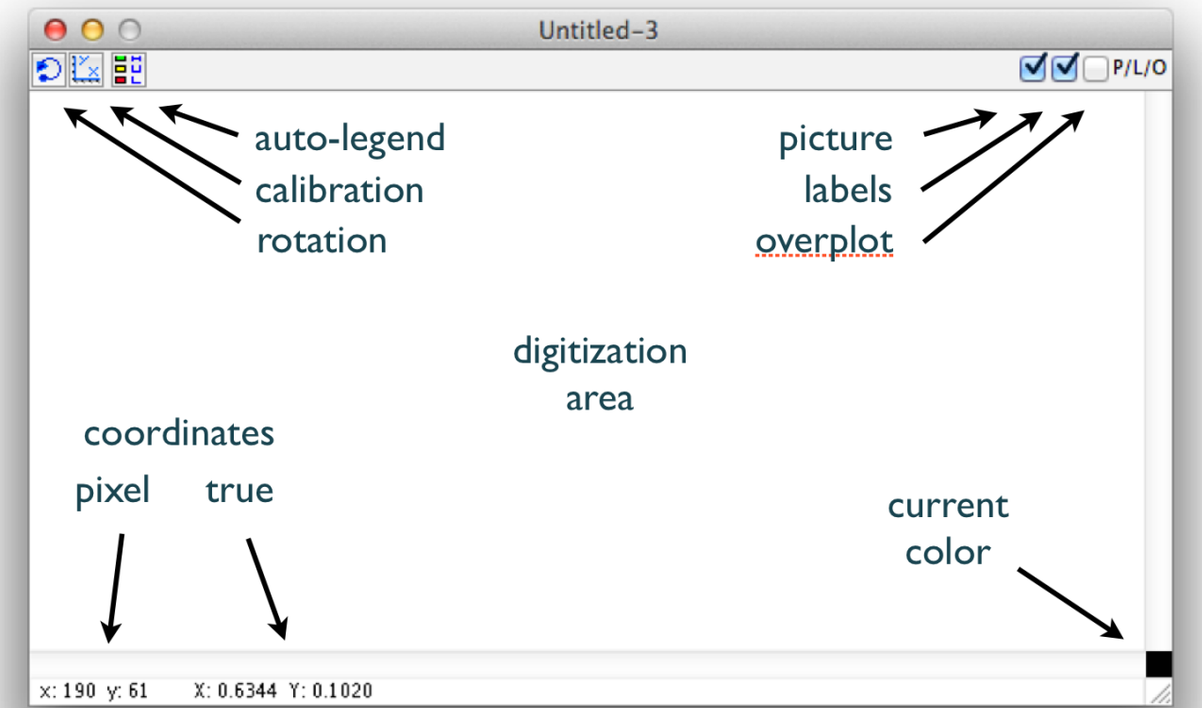


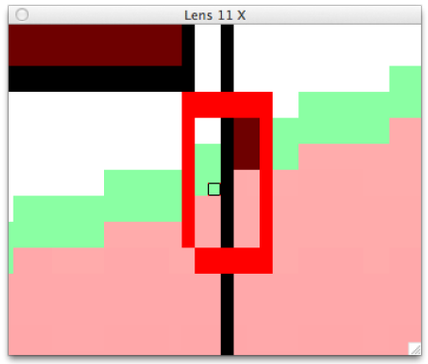



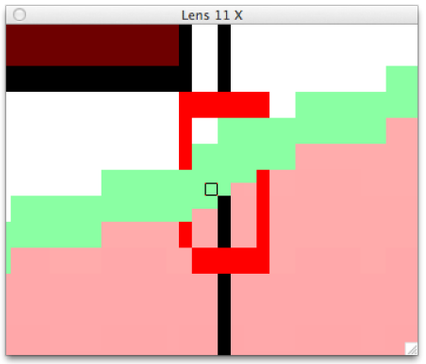



# From Google Earth to 2D profile

- Give a uniform color to the profile



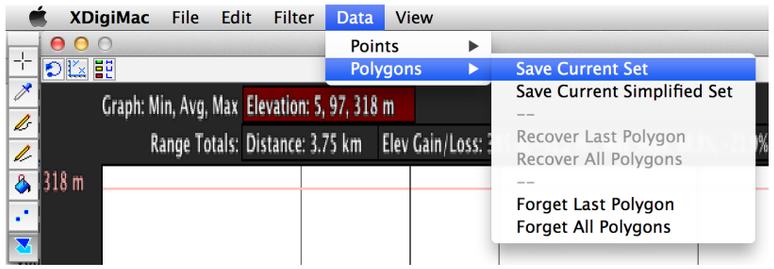


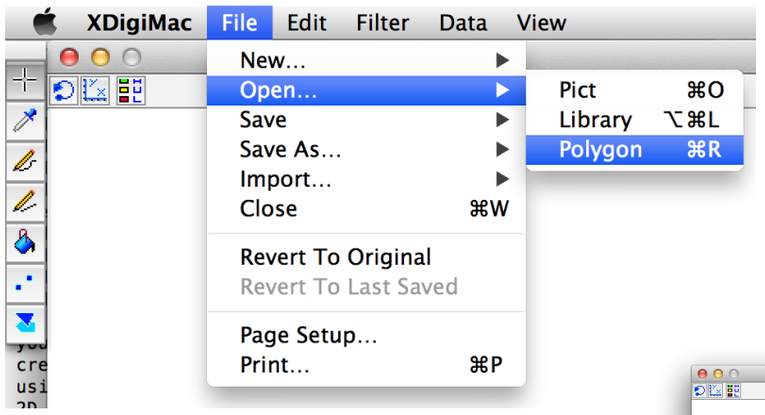


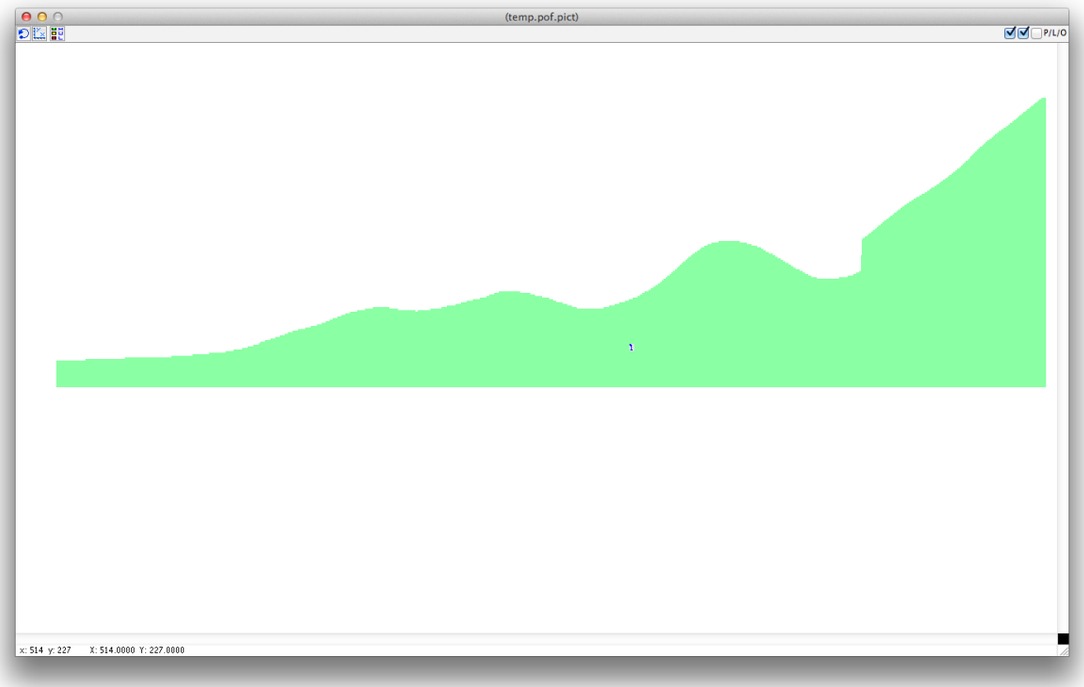
- Calibrate the digitizer

# From Google Earth to 2D profile

- Digitize the uniform polygon and read it in a new tablet

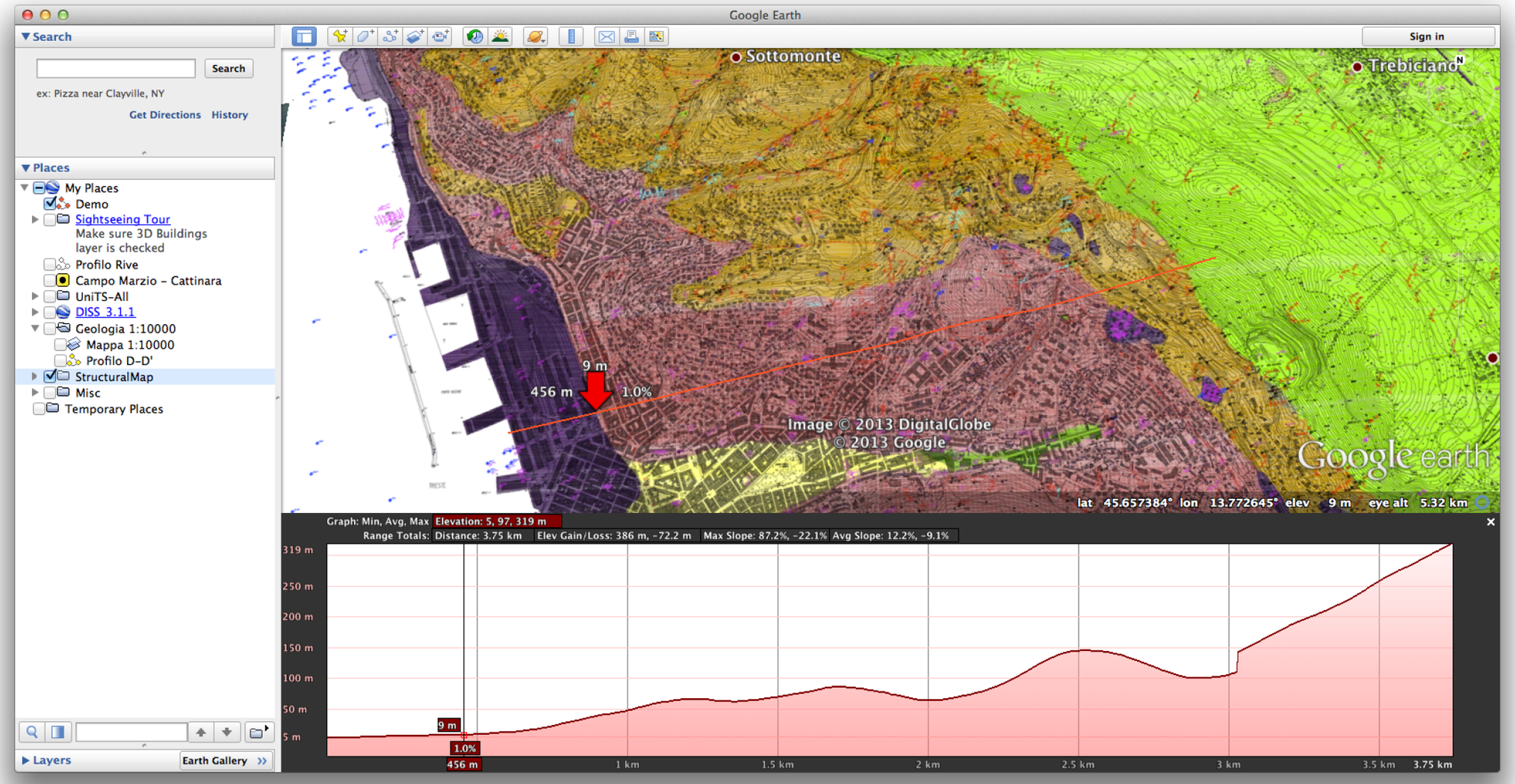


# From Google Earth to 2D profile

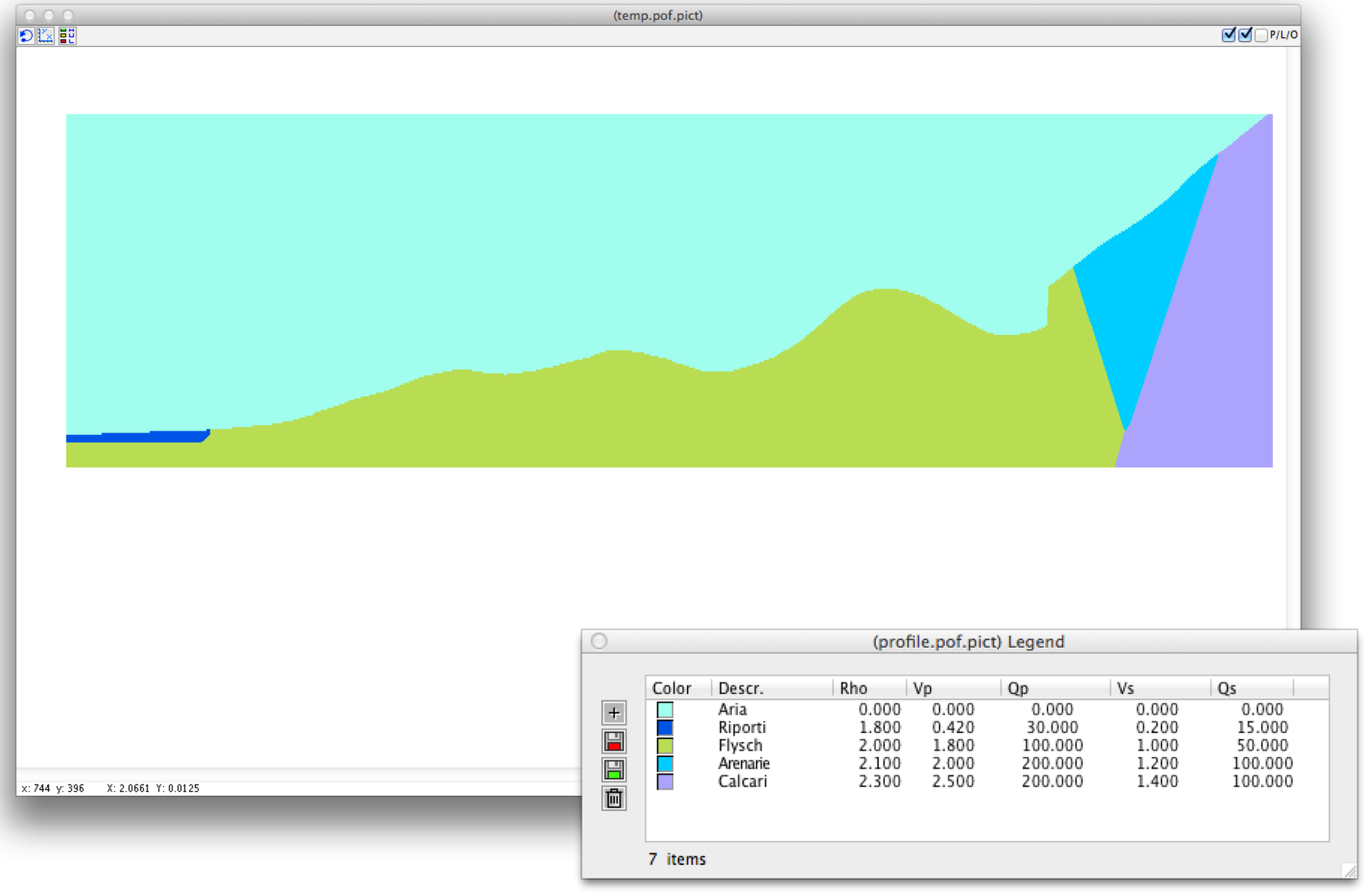
- Import a geologic map int Google Earth, and adjust its size so that it fits with the map




- Move the cursor along the elevation profile to read the distance of the geologic boundaries from the beginning of the profile, to be used in XDigiMac when drawing the layers

# From Google Earth to 2D profile

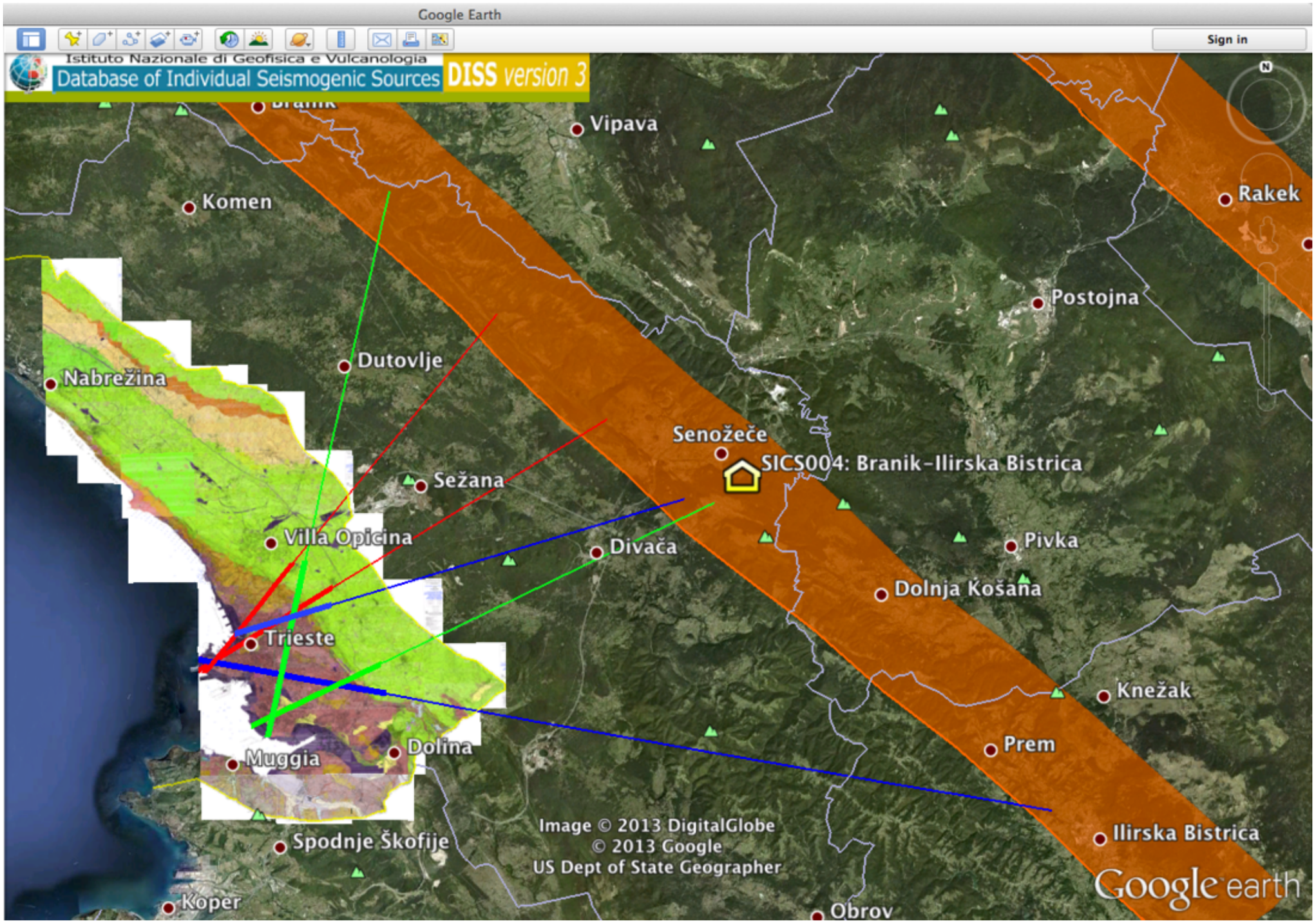
- Draw the layers in the cross-section, and define the layer properties, including the "air" layer that defines the topography




- Digitize the layers and save the .pof file that describe the profile

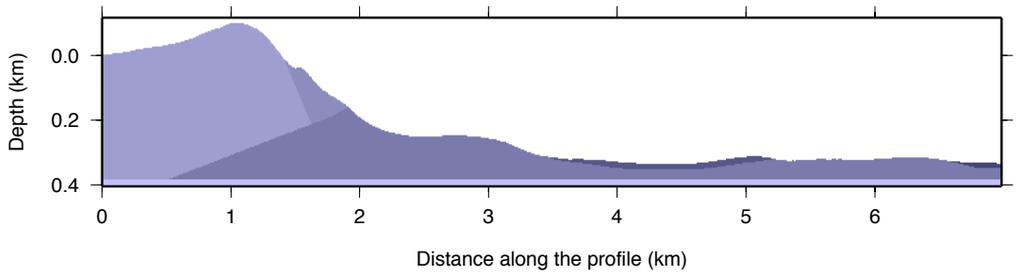
# Profiles

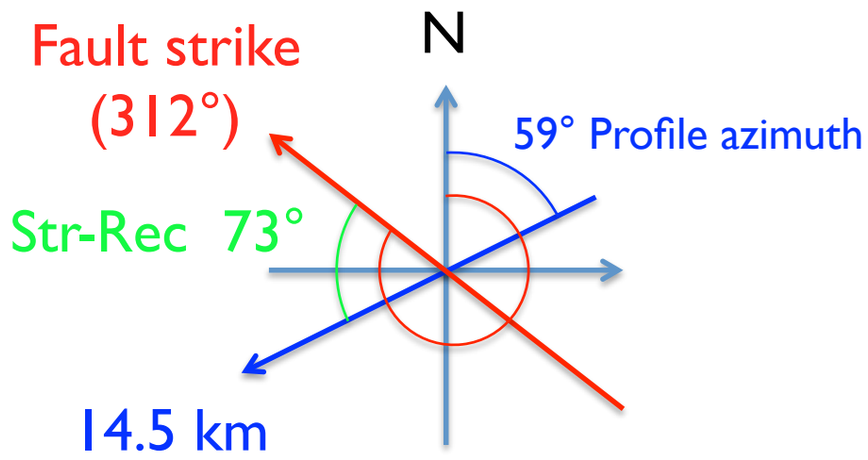
- Measure the azimuth of the profiles, and distance from the fault



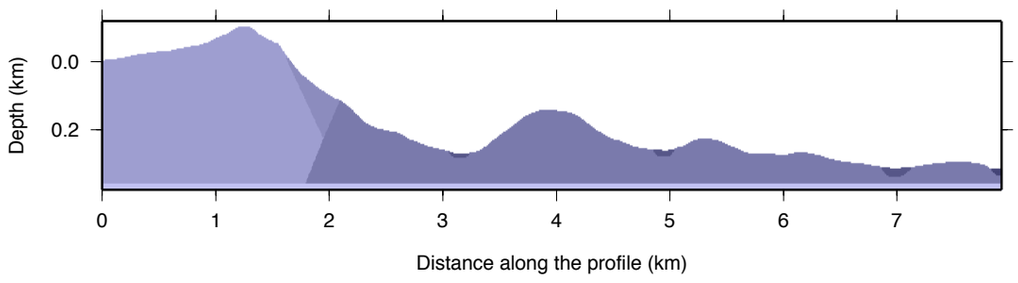
# Profiles: Strike-receiver angle computation

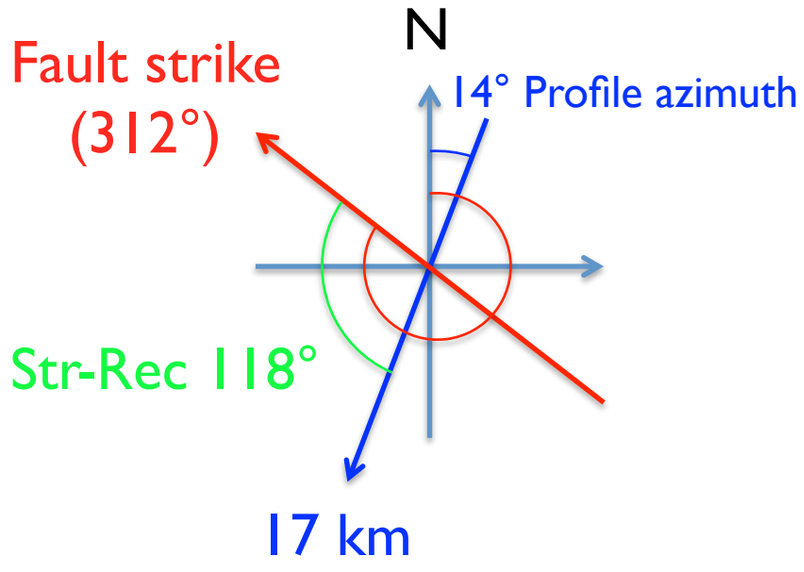
## Campo Marzio - Dip. di Fisica



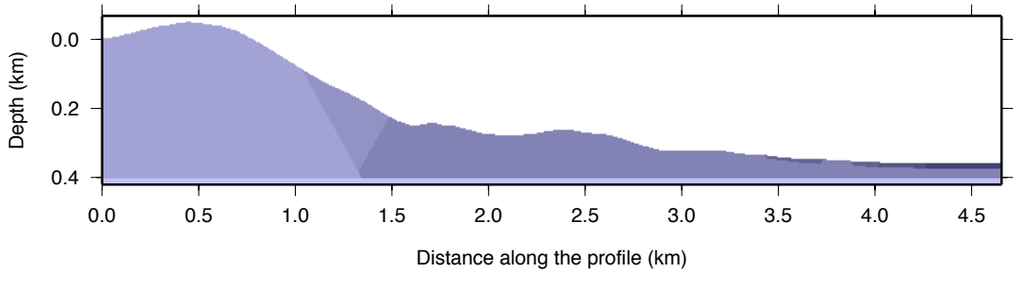



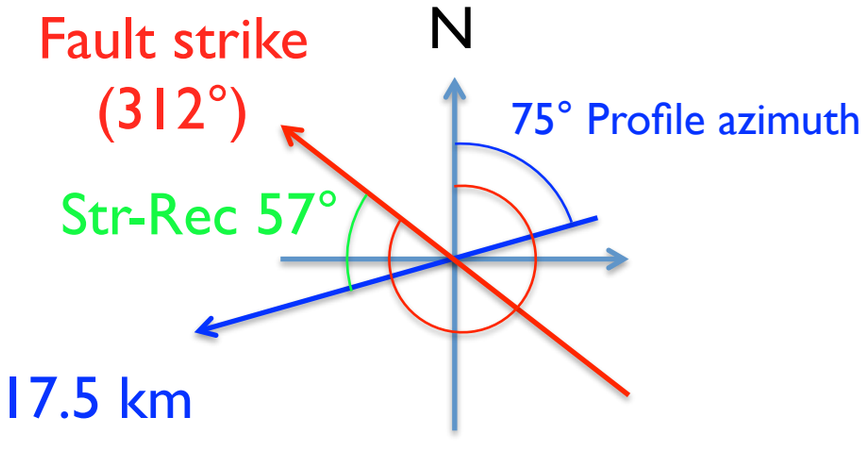

## Piazzale Valmaura - Via Weiss



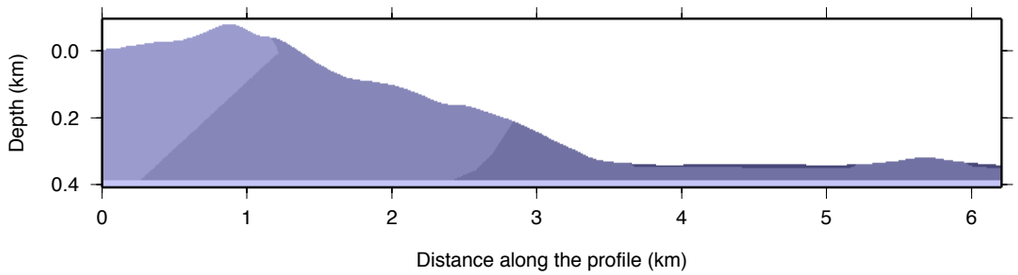

## Via Filzi - Via Weiss

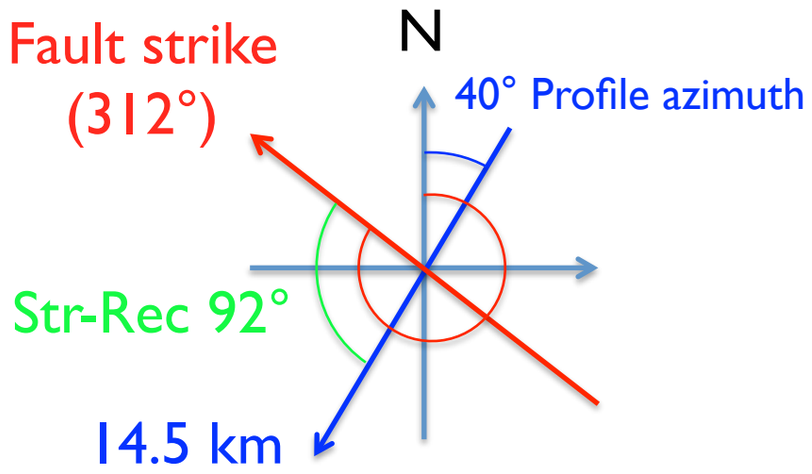


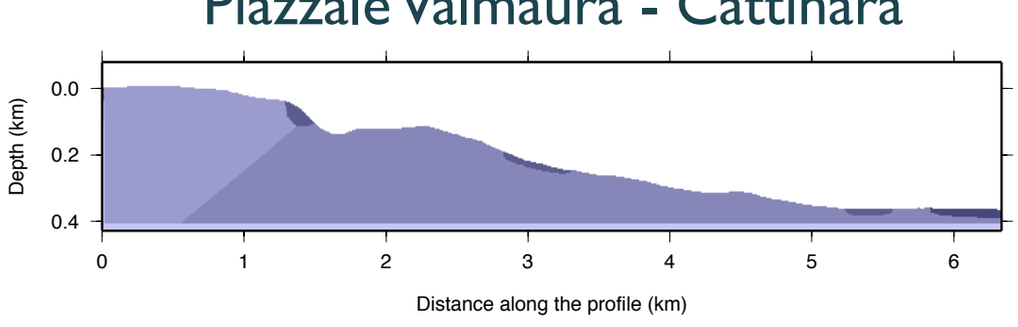
# Profiles: Strike-receiver angle computation

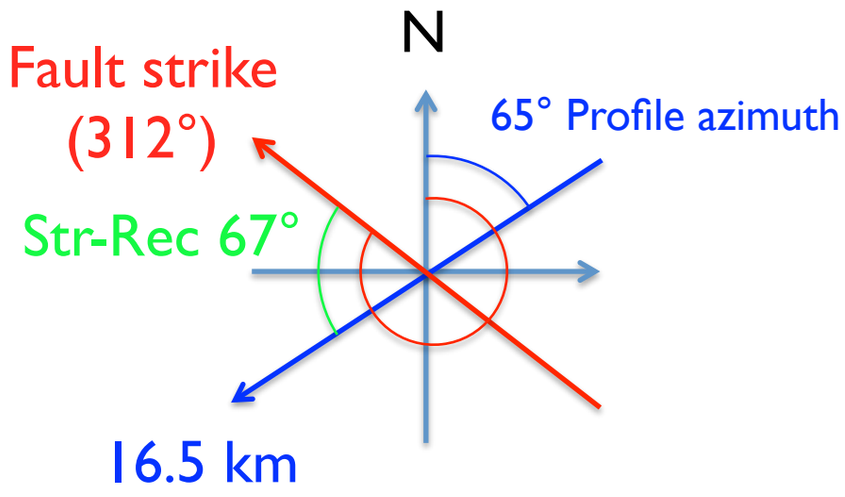
## V. Lazzaretto Vecchio - Via S. Anastasio



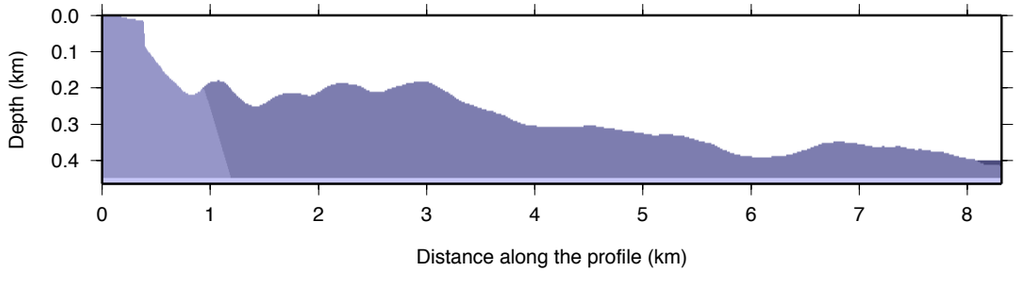



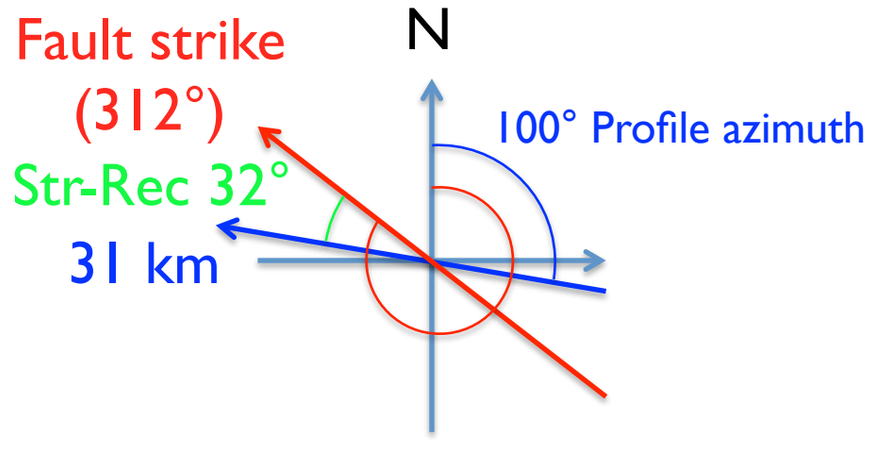

## Piazzale Valmaura - Cattinara




## Campo Marzio - Cattinara



# From Google Earth to 2D profile

## Complete the parameter file for 2D hybrid computations

```
Parameters file for program pfdg13 (v0002)
--------------------------------------------------------------------------
Modal summation model
--------------------------------------------------------------------------
bedrock.spr                          Modes for 1D structure
0         First mode to use (1=fundamental, 0=all)
0         Last mode to use (0=all)
10.0      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
1         High pass filter (0 no, 1 yes, 2 auto)
0.5       Lowest frequency in Hz with unit response
0.9       Ratio between cutoff and lowest freq with unit response
0.00      Amplitude at cutoff
0         Interpolation for modal summation part
8.        Source depth (km)
32.       Strike-receiver angle (SH modelling)
80.       Fault dip             (SH modelling)
170.      Fault rake            (SH modelling)
32.       Strike-receiver angle (P-SV modelling)
80.       Fault dip             (P-SV modelling)
170.      Fault rake            (P-SV modelling)
31.       Source-2D model origin distance (km)
5.5       Magnitude
1         Source (1=point, 2=extended)
none      File with source spectrum (only for extended source)
--------------------------------------------------------------------------
Finite differences model
--------------------------------------------------------------------------
cmca                                 Generated FD model
cm-ca.pof                            Polygons with 2D part definition
2800      Max number of grid points along x (max 2800)
2000      Max number of grind points along z (max 1000x1000)
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)
0.000     FD model length from 1st column of seismograms (km) (0=auto)
0.0       FD model depth (km) (0=auto)
0.000     Grid spacing (km) (0=auto)
8         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)
20        Time window length (s) for 1D SH (0=auto)
20        Time window length (s) for 1D P-SV (0=auto)
20        Time window length (s) for 2D SH (0=auto)
20        Time window length (s) for 2D P-SV (0=auto)
0         Shift in origin time (SH)
0         Shift in origin time (P-SV)
```

```
--------------------------------------------------------------------------
Seismograms
--------------------------------------------------------------------------
0         Model origin-first calculated seismogram distance (*) (0=auto)
0         Grid points between seismograms (0=auto)
0         File with indexes of seismogram to plot (0=plot all seismograms)
0         Plots the seismogram of the bedorck (0=no, 1=yes)
0         File with ordinates of user's points to plot (0=no ,filename user's choice)
3         Computes aver and max spectra (0=no,1=only each comp, 2=only global, 3=both)
0         File name of the normalizing spectrum (0=no,filename=file with spectrum)
0         Index of user seismograms to use as ref spectrum (0=no, must be from 1 to 4)
--------------------------------------------------------------------------
cntl files and scripts
--------------------------------------------------------------------------
1         Write cntl files (1=yes, 0=no)
1         Write script files (1=yes, 0=no)
0         Grid
--------------------------------------------------------------------------
programs used (in order: syl, syr, sylvdv, syndv, finit, finray)
--------------------------------------------------------------------------
syl0048.out
syr0048.out
sylvdv80.out
syndv80.out
finit80.out
finray80.out
--------------------------------------------------------------------------
Comments
--------------------------------------------------------------------------
(*) D*** (km): distance of the first site from the model origin
               (D.20: .200 km from the model origin)
    P*** (-) : number of grid steps from the model origin to the
               first site
               (P20: grid step of .010 km --> distance of .20 km)

columns--->           ms  ms+1 ms+2
             *|   *    *    *   |*
 adsorbing   *|   *    *    *   |*      2D model
   zone      *|   *    *    *   |*
             *|   *    *    *   |*

ms  : 1st column of input seismograms
ms+1: 2nd column of input seismograms
```