GROUND MOTION PARAMETERS EXTRACTION WITH ANTELOPE AND PYTHON

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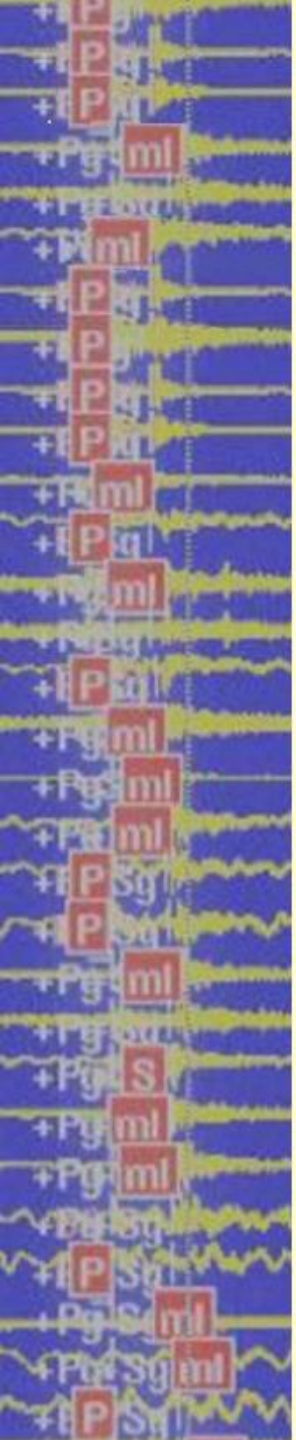
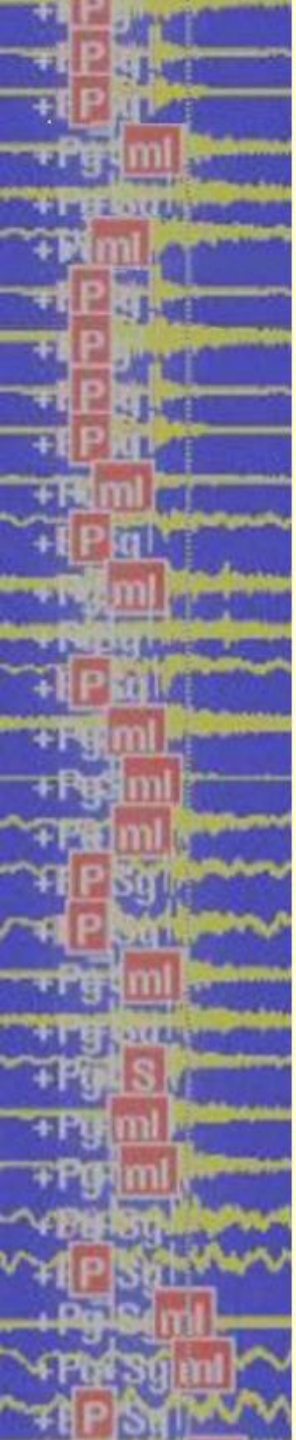
Seismological Research and Monitoring Group



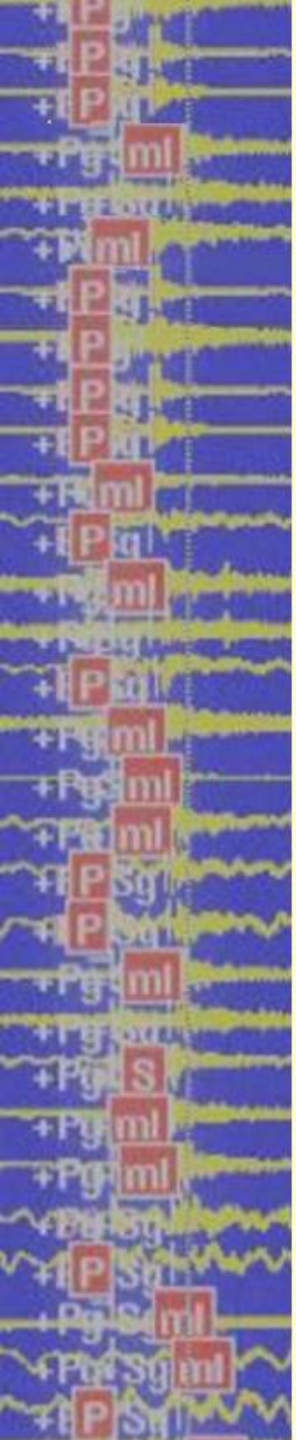
Why *GMP_Viewer*

Python script for Ground Motion Parameters (GMP) extraction from seismic waveforms in Antelope databases



GMP_Viewer main concept

- modularity: any new parameter calculation can be added
- control: high customization of signal processing for each individual trace
- clarity: synthetic graphical visualization of the results

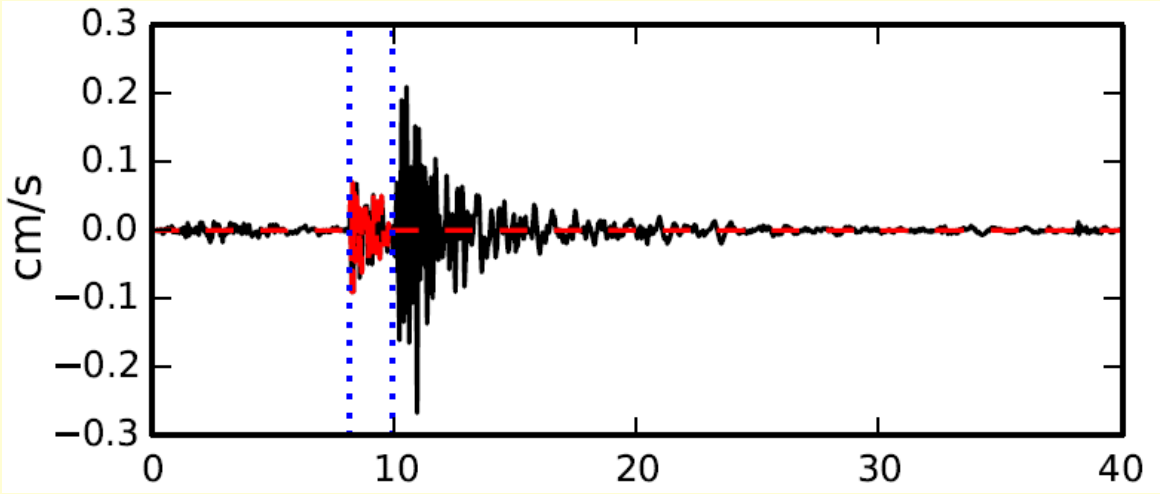


Currently available GMPs

- PGA
- PGV
- PGD
- PGV/PGA
- duration
- PSA03
- PSA10
- PSA30
- zero crossings
- Saragoni factor
- Manfredi damage factor
- Arias intensity
- Housner intensity
- EPA
- IV2

Currently available GMPs: IV2

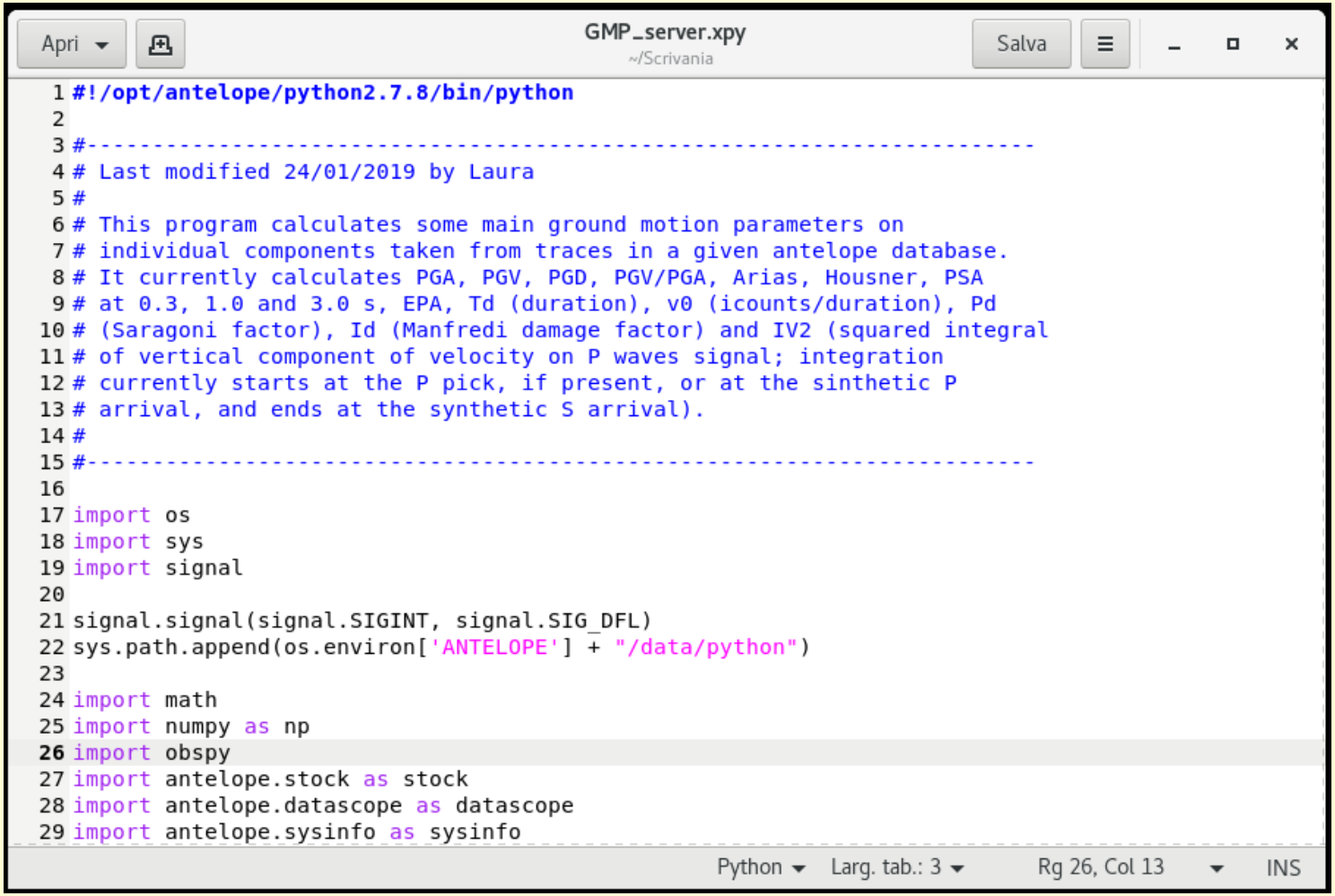
$$IV2 = \int_t^{t+\Delta t} v_z^2(t)dt \quad with \quad t = t_P,\ t + \Delta t = t_S$$



Kanamori, H., E. Hauksson, L. K. Hutton, and L. M. Jones (1993), Determination of earthquake energy release and ML using TERRAscope, *Bull. Seismol. Soc. Am.*, 83, 330–346

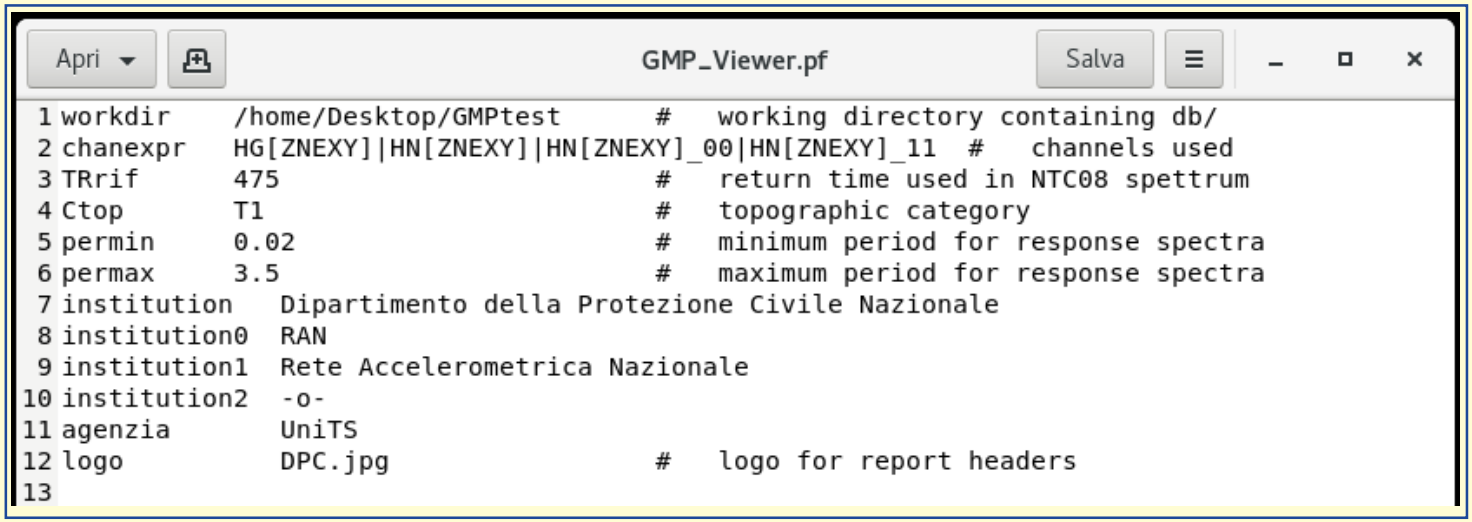
Picozzi, M., Bindi, D., Brondi, P., Di Giacomo, D., Parolai, S., and Zollo, A. (2017), Rapid determination of P wave-based energy magnitude: Insights on source parameter scaling of the 2016 Central Italy earthquake sequence, *Geophys. Res. Lett.*, 44, 4036– 4045

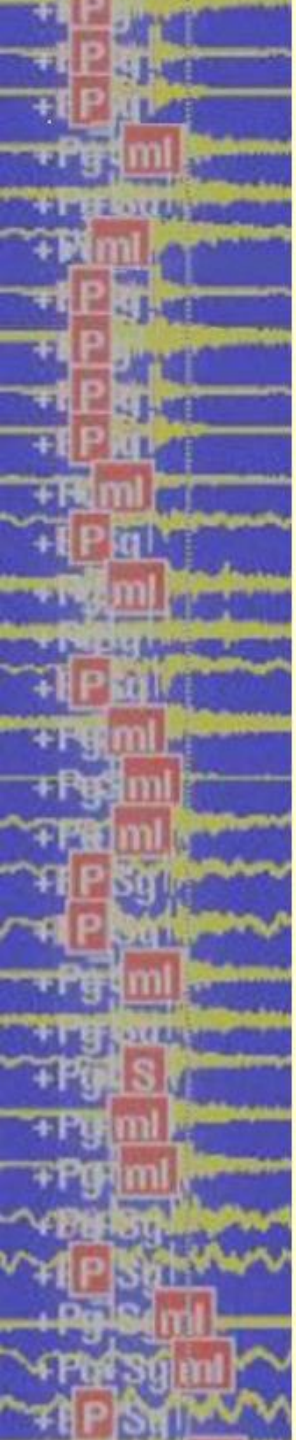
A look at the code



Running the code

> GMP_Viewer.xpy pf/GMP_Viewer.pf



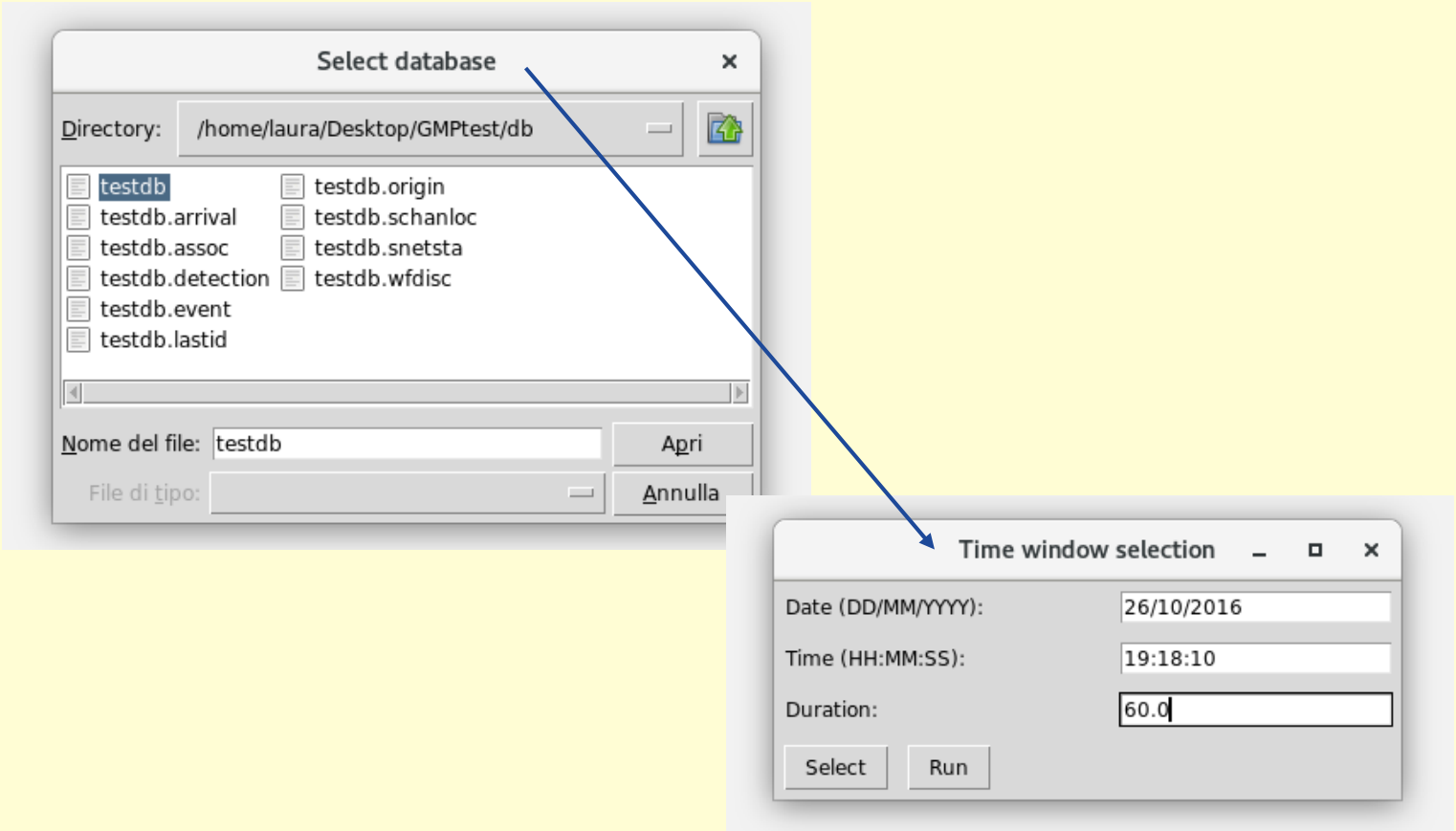


Running the code

Requirements:

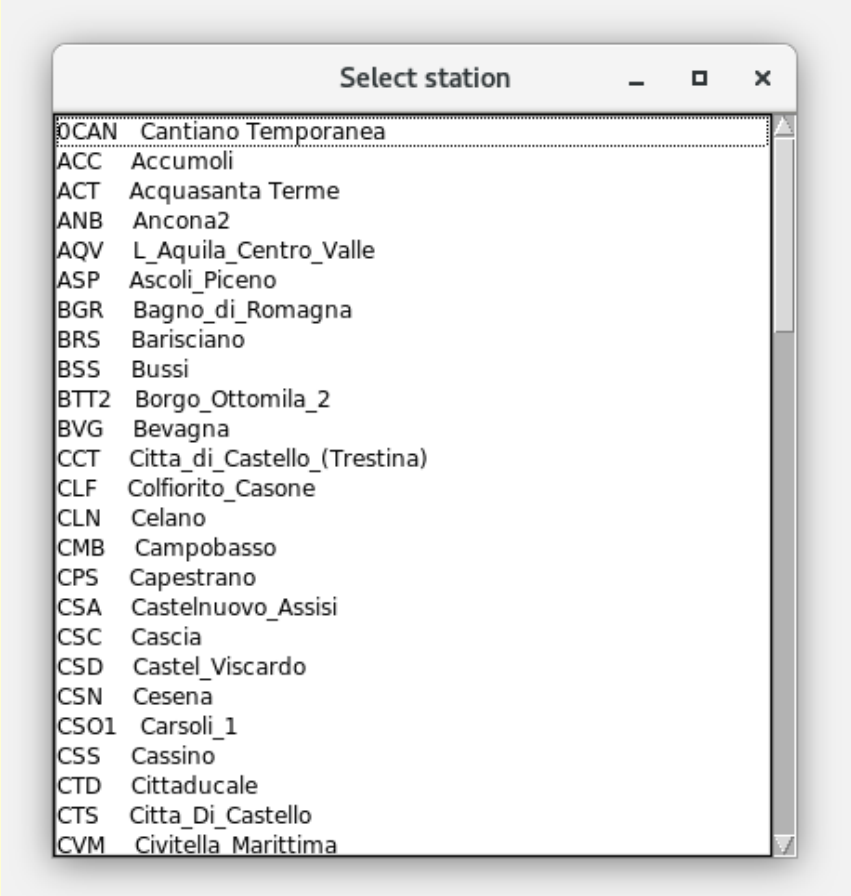
- Python: *obspy, matplotlib, numpy, scipy, time, Tkinter, tkFileDialog, contextlib, datetime, math, signal, PIL*
- Antelope
- An Antelope database with some tables already available (*sitechan*, *site*, *schanloc*, *wfdisc*); some are optional (*arrival*, *assoc; origin*, *event; calibration; stage; Geosite, Spetpar*)

Waveform selection (I)



E.g.: event of October 26th 2016, 19:18:06,
Central Italy sequence, M_W = 5.9

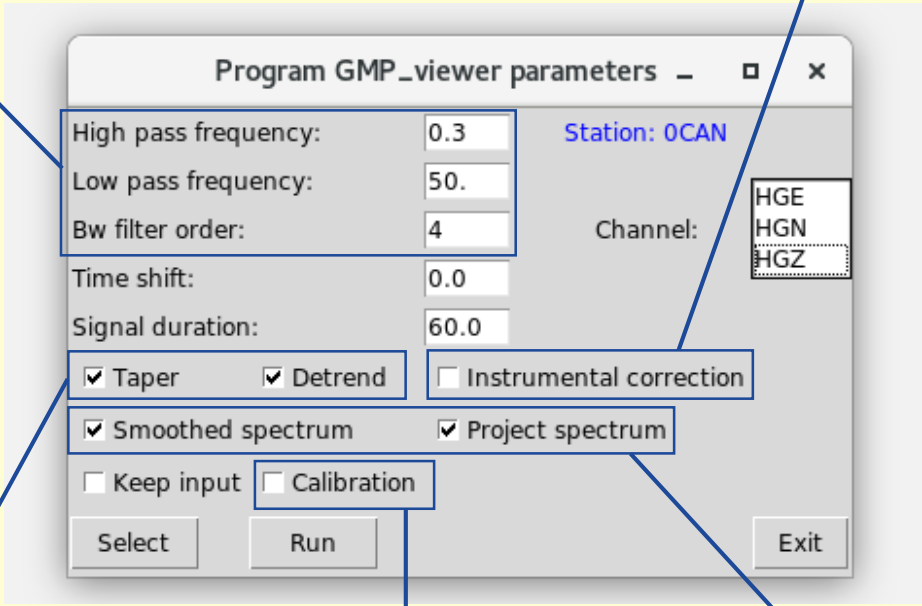
Waveform selection (II)



Waveform manipulation

Butterworth filter

instrumental correction



tapering & detrending

calibration

response spectra

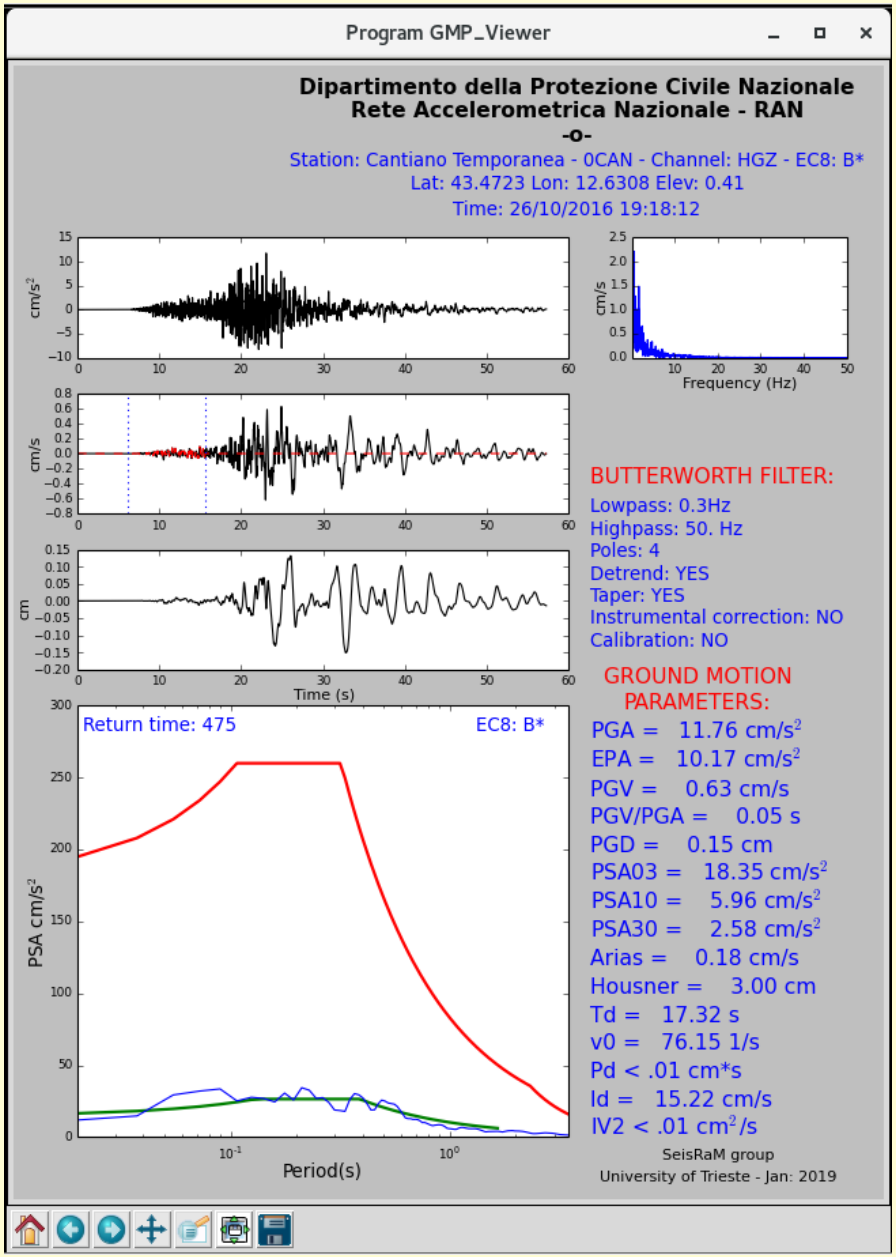
Output

txt + pdf

Apri | 2016300_191810_0CAN_HGZ.txt

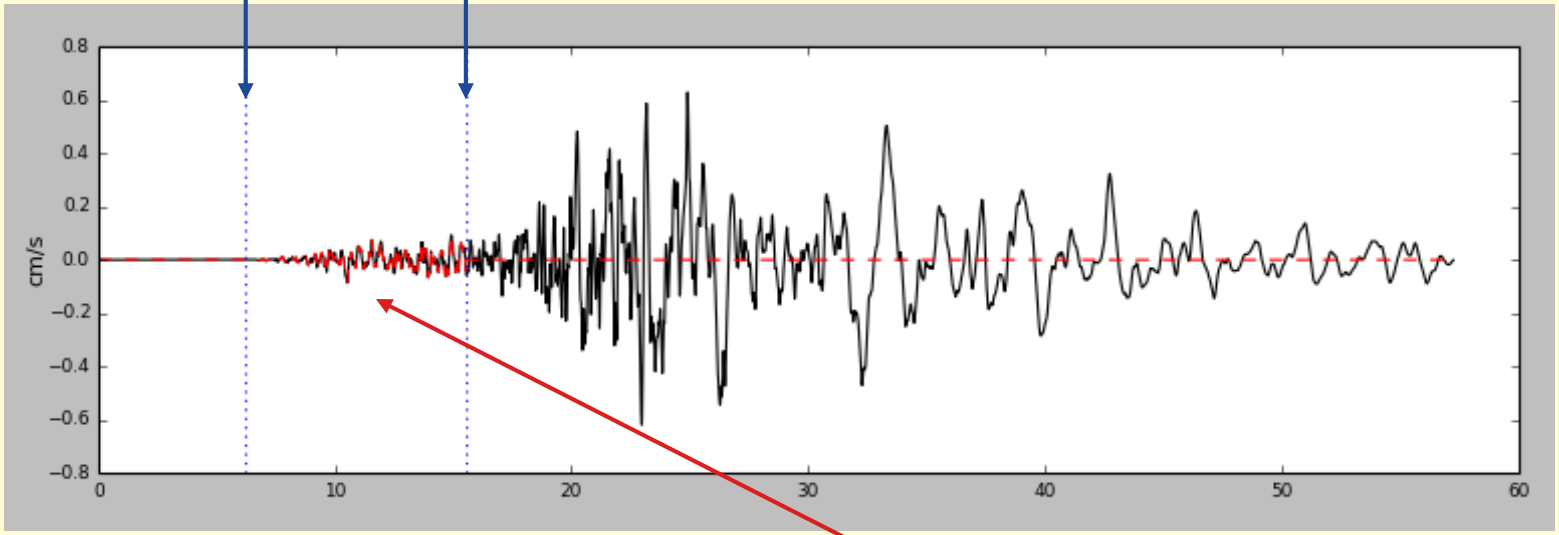
1	pga	11.76
2	epa	10.17
3	pgv	0.63
4	pgv/pga	0.05
5	pgd	0.15
6	psa03	18.35
7	psa10	5.96
8	psa30	2.58
9	arias	0.18
10	housner	3.00
11	Td	17.32
12	v0	76.15
13	Pd	< .01 cm*s
14	Id	15.22
15	IV2	< .01 cm^2/s

Testo semplice | Larg. tab.: 3 | Rg 1, Col 1 | INS



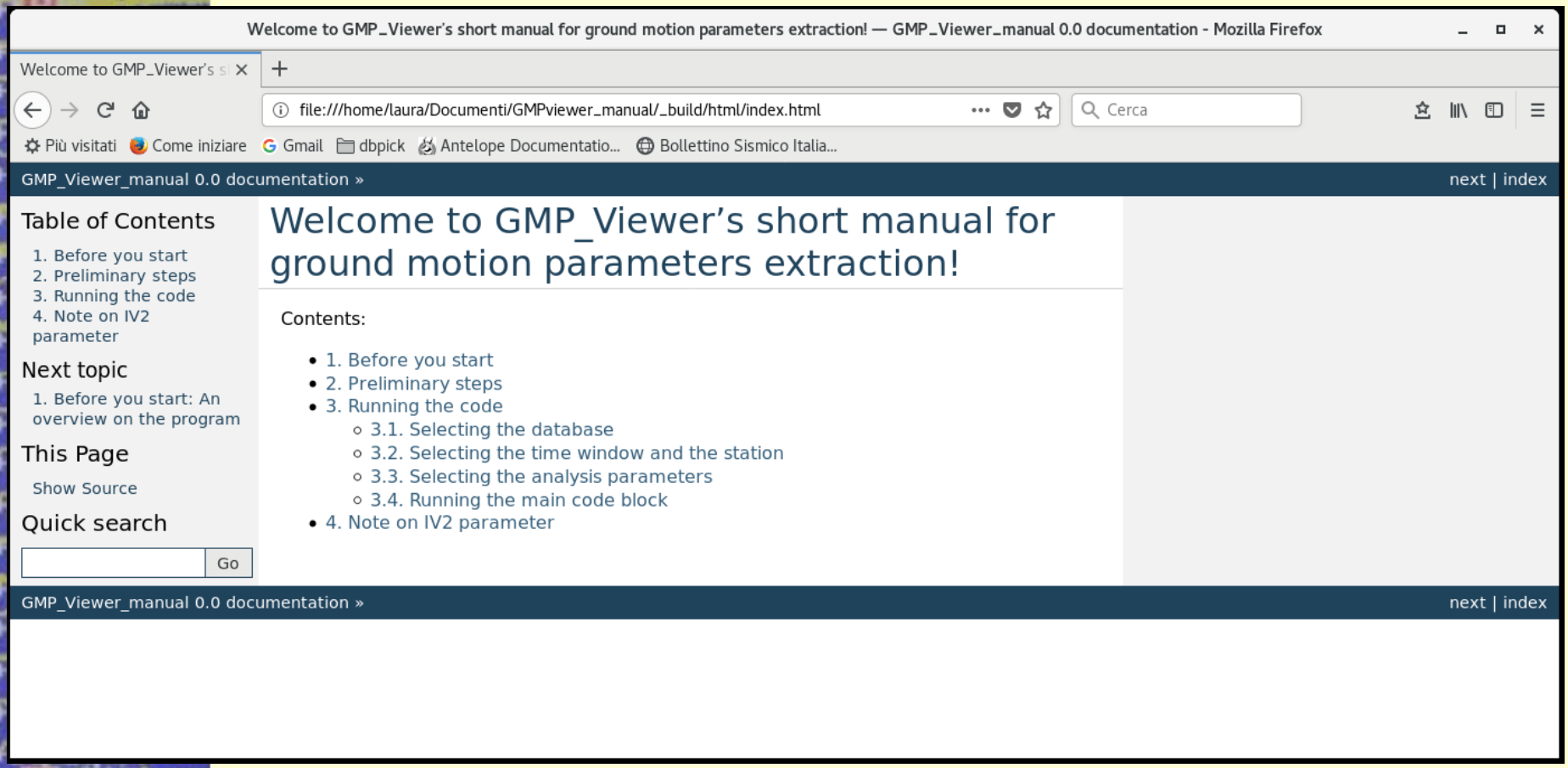
Output: IV2

Synthetic P and S picks

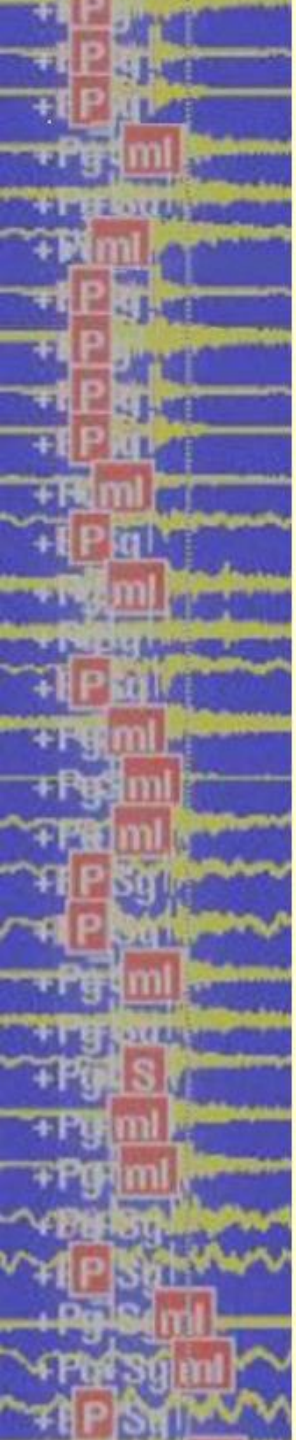


Trace used for integration

Documentation



Example of application: GMICEs



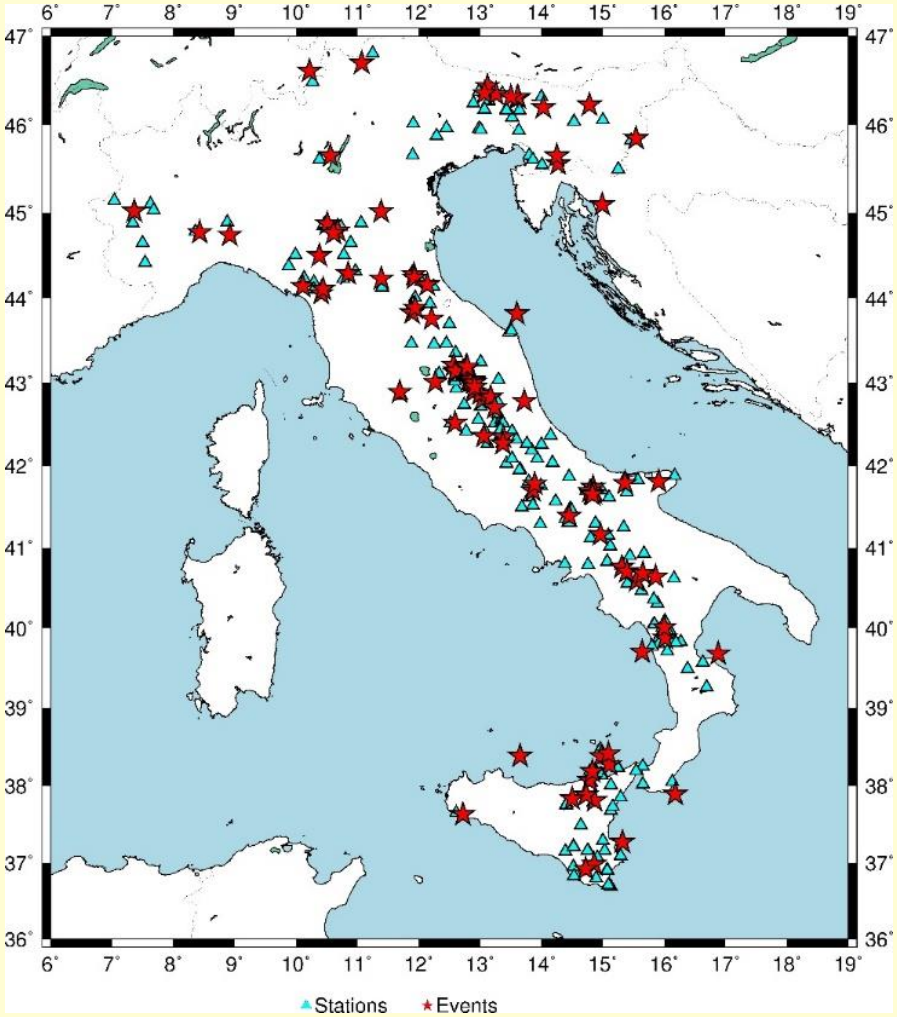
Database

GMP_Viewer

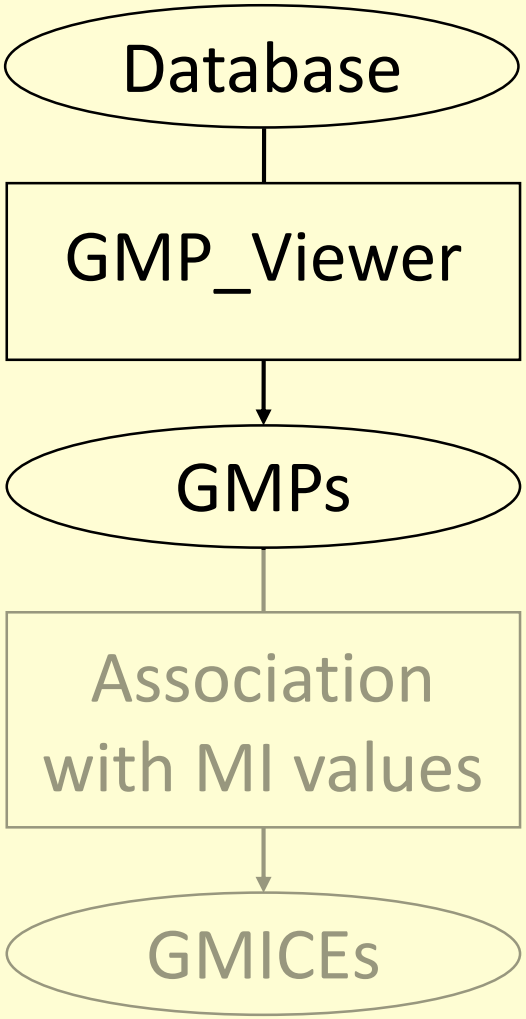
GMPs

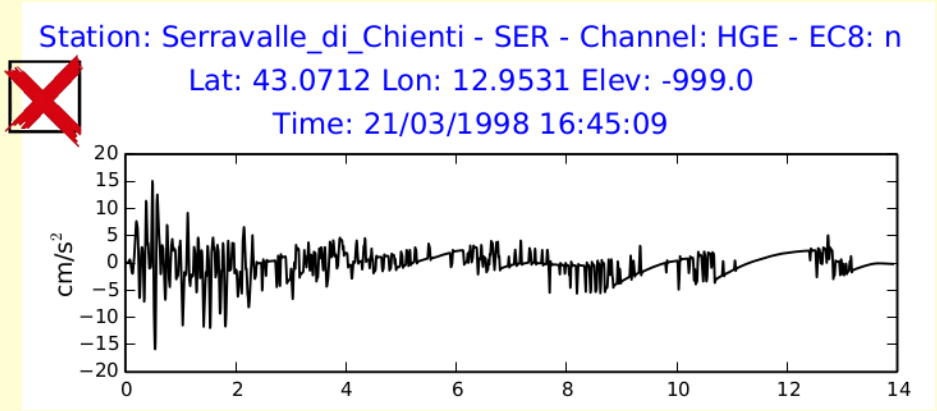
Association with MI values

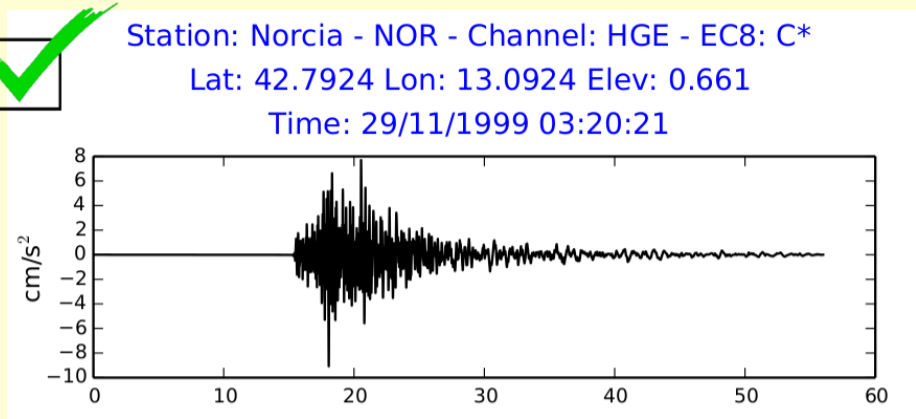
GMICEs



Example of application: GMICEs







Example of application: GMICEs

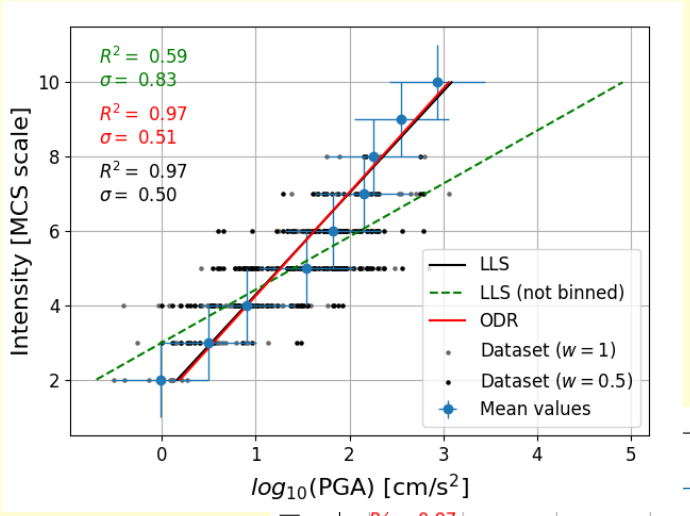
Database

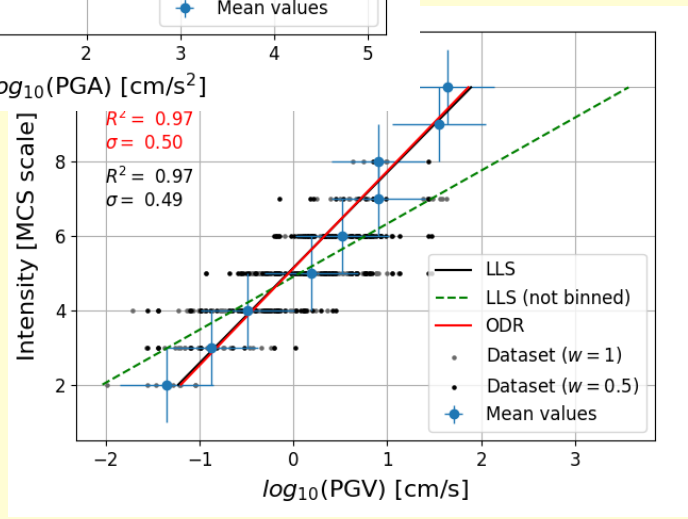
GMP_Viewer

GMPs

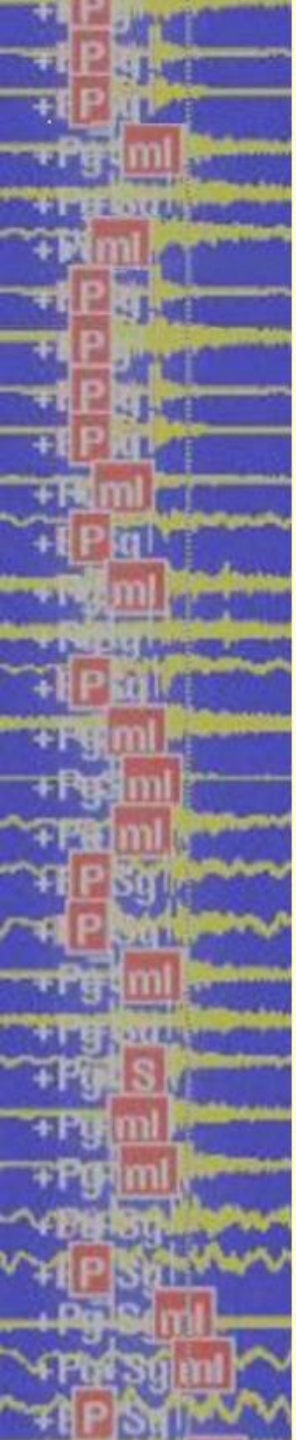
Association with MI values

GMICEs





$$I = a + b\log(GMP)$$



Pros and cons

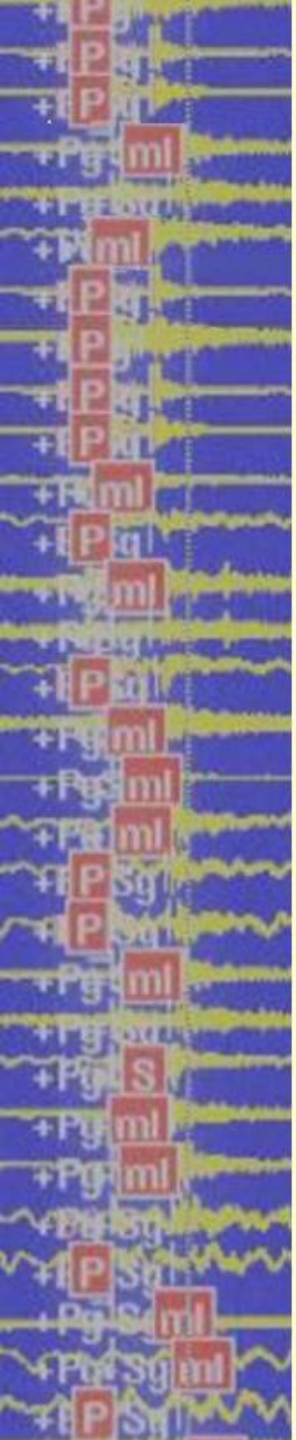
– works on one trace at a time (can control the analysis parameters)

– works on one component at a time (need to manually select the absolute peak values)

– does not perform event detection or event information extraction

– useful for databases with known issues in the event detection

– …



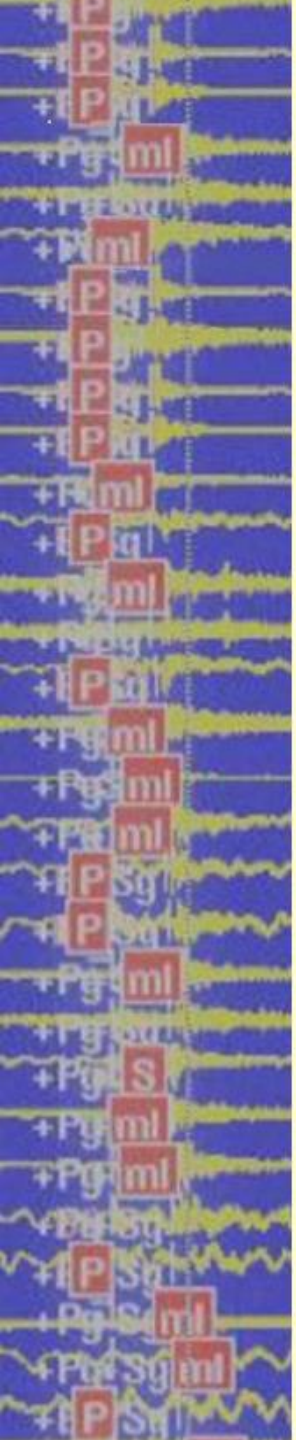
Future developments

– perform phase pickings

– analyse three components at the same time (no need to manually select the absolute peak values)

– implement the code as a python library

– …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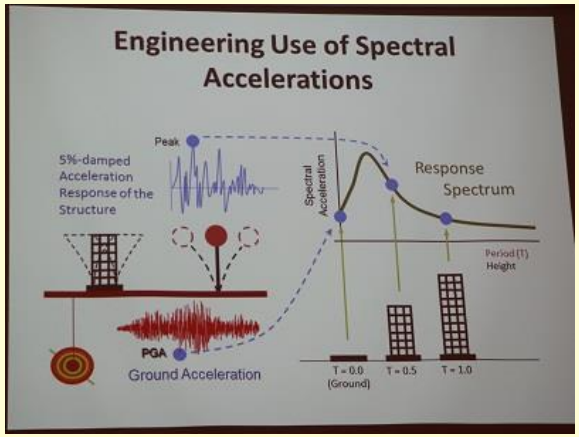
Currently available GMPs

EPA (Effective Peak Acceleration)

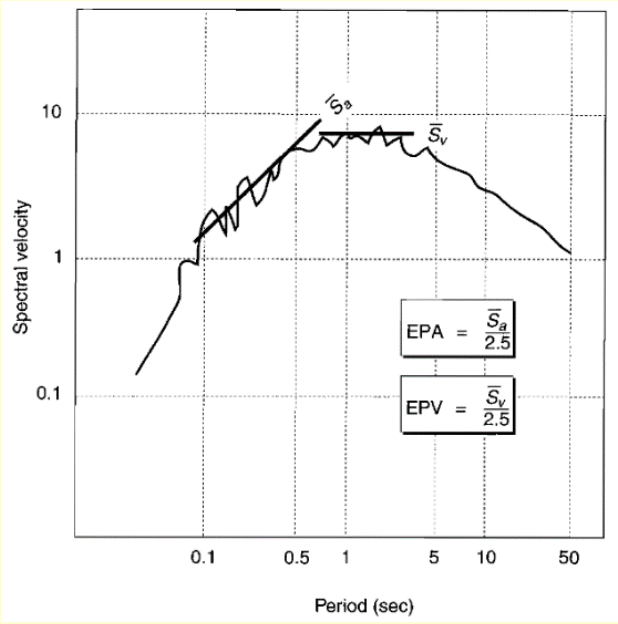
Average spectral acceleration over the period range 0.1 to 0.5 sec divided by 2.5 (the standard amplification factor for a 5% damping spectrum)

PSA03, PSA10, PSA30

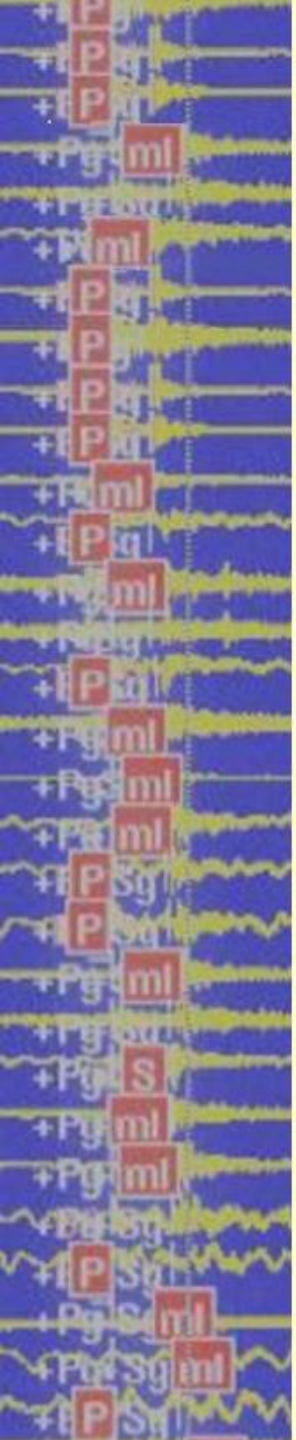
5%-damped acceleration response of a SDOF oscillator at different periods



https://www.seismology.az/en/news/274



Kramer, Geotechnical Earthquake Engineering, 1996



Currently available GMPs

duration

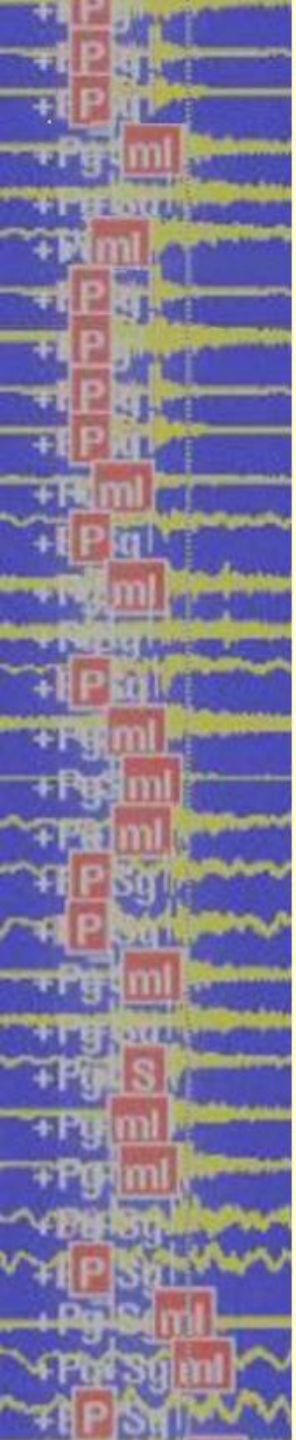
Duration of the signal containing from 5% to 95% of the total energy

Arias intensity

$$I_A = \frac{\pi}{2g} \int_0^{T_d} a^2(t)\, dt$$

Housner intensity

$$I_H(\xi = 5\%) = \frac{\pi}{2g} \int_{0.1}^{2.5} PSV(T, \xi = 5\%)\, dT$$



Currently available GMPs

zero crossings (v_0)

Number of zero crossings per second for the signal containing between 5% and 95% of the total energy

Saragoni factor

$$P_D = \frac{I_A}{v_0^2}$$

Manfredi damage factor

$$M_F = \frac{2g}{\pi} \frac{I_A}{PGA \times PGV}$$

Eurocode 8 site classification

Table 3.1: Ground types

Ground type	Description of stratigraphic profile	Parameters		
		$v_{s,30}$ (m/s)	N_{SPT} (blows/30cm)	c_u (kPa)
A	Rock or other rock-like geological formation, including at most 5 m of weaker material at the surface.	> 800	–	–
B	Deposits of very dense sand, gravel, or very stiff clay, at least several tens of metres in thickness, characterised by a gradual increase of mechanical properties with depth.	360 – 800	> 50	> 250

https://eurocodes.jrc.ec.europa.eu/doc/WS_335/S1_EC8-Lisbon_E%20CARVALHO.pdf

Eurocode 8 site classification

Table 3.1: Ground types

Ground type	Description of stratigraphic profile	Parameters		
		$v_{s,30}$ (m/s)	N_{SPT} (blows/30cm)	c_u (kPa)
C	Deep deposits of dense or medium-dense sand, gravel or stiff clay with thickness from several tens to many hundreds of metres.	180 – 360	15 - 50	70 - 250
D	Deposits of loose-to-medium cohesionless soil (with or without some soft cohesive layers), or of predominantly soft-to-firm cohesive soil.	< 180	< 15	< 70

https://eurocodes.jrc.ec.europa.eu/doc/WS_335/S1_EC8-Lisbon_E%20CARVALHO.pdf

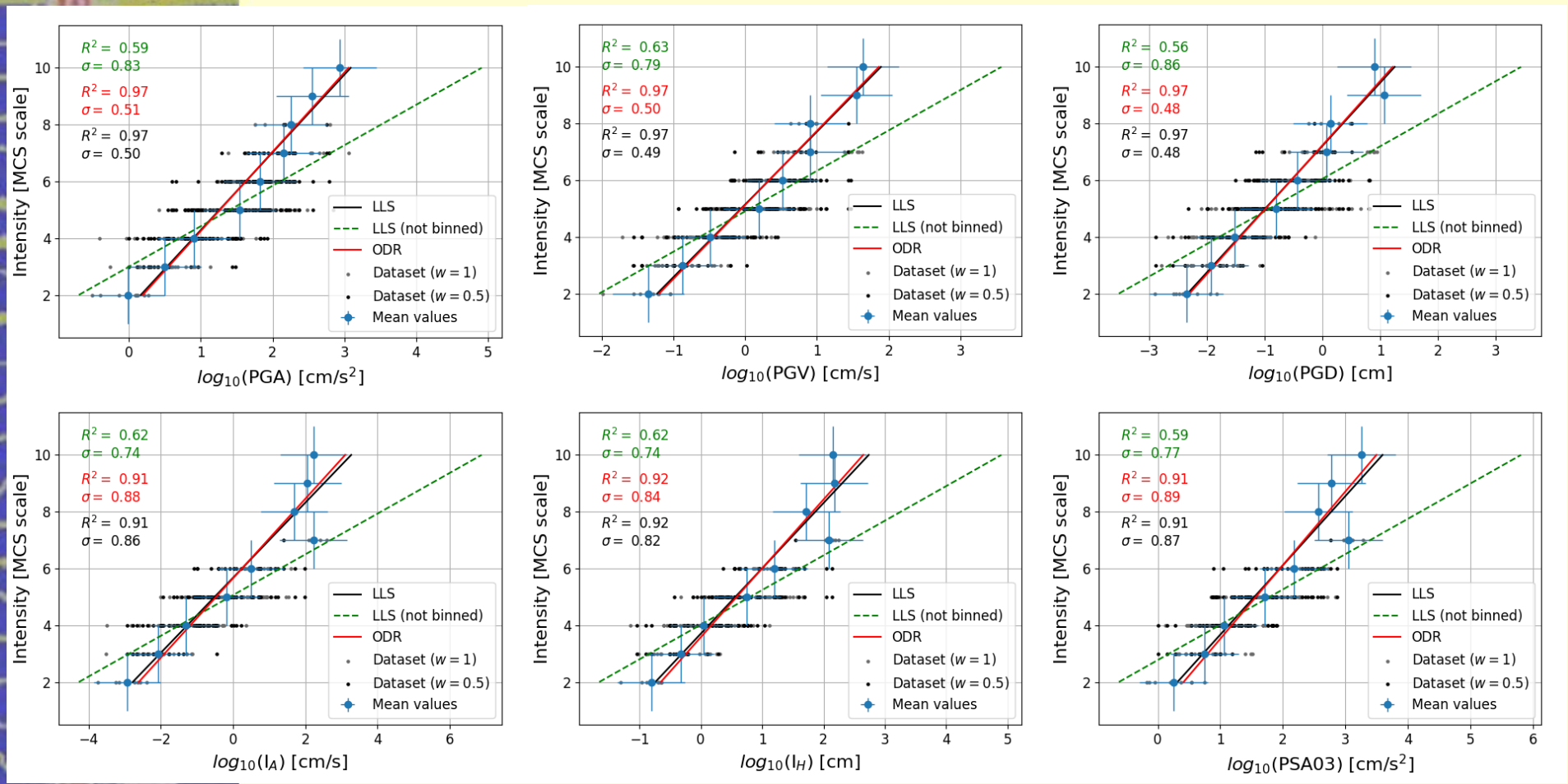
Eurocode 8 site classification

Table 3.1: Ground types

Ground type	Description of stratigraphic profile	Parameters		
		$v_{s,30}$ (m/s)	N_{SPT} (blows/30cm)	c_u (kPa)
E	A soil profile consisting of a surface alluvium layer with v_s values of type C or D and thickness varying between about 5 m and 20 m, underlain by stiffer material with $v_s > 800$ m/s.			
S_1	Deposits consisting, or containing a layer at least 10 m thick, of soft clays/silts with a high plasticity index (PI > 40) and high water content	< 100 (indicative)	_	10 - 20
S_2	Deposits of liquefiable soils, of sensitive clays, or any other soil profile not included in types A – E or S_1			

https://eurocodes.jrc.ec.europa.eu/doc/WS_335/S1_EC8-Lisbon_E%20CARVALHO.pdf

$$I = a + b\log(GMP)$$


$R^2 = 0.59$
$\sigma = 0.83$
$R^2 = 0.97$
$\sigma = 0.51$
$R^2 = 0.97$
$\sigma = 0.50$
LLS
LLS (not binned)
ODR
Dataset ($w = 1$)
Dataset ($w = 0.5$)
Mean values
Intensity [MCS scale]
log_{10}(PGA) [cm/s^2]
$R^2 = 0.63$
$\sigma = 0.79$
$R^2 = 0.97$
$\sigma = 0.50$
$R^2 = 0.97$
$\sigma = 0.49$
log_{10}(PGV) [cm/s]
$R^2 = 0.56$
$\sigma = 0.86$
$R^2 = 0.97$
$\sigma = 0.48$
$R^2 = 0.97$
$\sigma = 0.48$
log_{10}(PGD) [cm]
$R^2 = 0.62$
$\sigma = 0.74$
$R^2 = 0.91$
$\sigma = 0.88$
$R^2 = 0.91$
$\sigma = 0.86$
log_{10}(I$_A$) [cm/s]
$R^2 = 0.62$
$\sigma = 0.74$
$R^2 = 0.92$
$\sigma = 0.84$
$R^2 = 0.92$
$\sigma = 0.82$
log_{10}(I$_H$) [cm]
$R^2 = 0.59$
$\sigma = 0.77$
$R^2 = 0.91$
$\sigma = 0.89$
$R^2 = 0.91$
$\sigma = 0.87$
log_{10}(PSA03) [cm/s^2]