Tutorial 6
GMPE Selection

GMPE Selection Criteria

For regional hazard study it not practical to implement a new GMPE each time. Existing relations must be used.

But how to select the proper GMPE?

A) If local data available (not common):

→ Compare and select the best matching GMPE

B) If data not available (most cases):

→ Select best GMPE based on indirect criteria (e.g. Cotton et al 2006)

- Similarity of region type
- Robustness of calibration data
- Suitability of functional form
- Is state-of-art

GMPE Selection Criteria

Define a selection criteria and select three GMPEs (implemented in OQ) to be used in your model via a ground motion logic tree. Assign branch weights based on your confidence in the GMPEs. Justify your selection and weighting.

Recommended (minimum) selection criteria:

1. Is consistent with the tectonic region (TR) of your area
   - Common TRs: Active Shallow Crust, Subduction Interface, Subduction Intraslab, Stable Continental
   - See: https://docs.openquake.org/oq-engine/master/openquake.hazardlib.gsim.html
2. Represents the magnitudes and distances in your source model
   - Refer to GMPE publications and http://gmpe.org.uk/gmpereport2014.html
3. Is the most up-to-date form
   - e.g. Chiou and Youngs (2008) has been superseded by Chiou and Youngs (2014)

More selection criteria

Cotton et al. (2006)

The following are criteria that could be considered for rejecting equations from the complete list of available candidate models, arranged in order of descending hierarchy:

1. The model is from a clearly irrelevant tectonic regime.
2. The model is not published in an international peer-reviewed journal.
3. The documentation of model and its underlying dataset is insufficient.
4. The model has been superseded by more recent publications.
5. The frequency range of the model is not appropriate for engineering application.
6. The model has an inappropriate functional form.
7. The regression method or regression coefficients are judged to be inappropriate.

Bommer et al. (2010)

1. Model is derived for an inappropriate tectonic environment (such as subduction-zone earthquakes or volcanic regions).
2. Model not published in a Thomson Reuters ISI-listed peer-reviewed journal (although an exception can be made for an update to a model that did meet this criterion).
3. The dataset used to derive the model is not presented in an accessible format; the minimum requirement would be a table listing the earthquakes and their characteristics, together with the number of records from each event.
4. The model has been superseded by a more recent publication.
5. The model does not provide spectral predictions for an adequate range of response periods, chosen here to be from 0.0 to 2.0 seconds.
6. The functional form lacks either non-linear magnitude dependence or magnitude-dependent decay with distance.
7. The coefficients of the model were not determined with a method that accounts for inter-event and intra-event components of variability; in other words, models must be derived using one- or two-stage maximum likelihood approaches or the random effects approach.
8. Model uses inappropriate definitions for explanatory variables, such as M_L or R_{epi}, or models site effects without consideration of V_{s30}.
9. The range of applicability of the model is too small to be useful for the extrapolations generally required in PSHA: $M_{min} > 5$, $M_{max} < 7$, $R_{max} < 80$ km.
10. Model constrained with insufficiently large dataset: fewer than 10 earthquakes per unit of magnitude or fewer than 100 records per 100 km of distance. The open circles in Figure 3 represent models failing this criterion.

GMPEs in OpenQuake

GEM

OpenQuake includes one of the most comprehensive libraries of GMPEs (“GSIMs”) for the most common tectonic regions considered in SHA e.g. active shallow crust, stable continental region, subduction interface, subduction inslab, with 100+ GMPEs

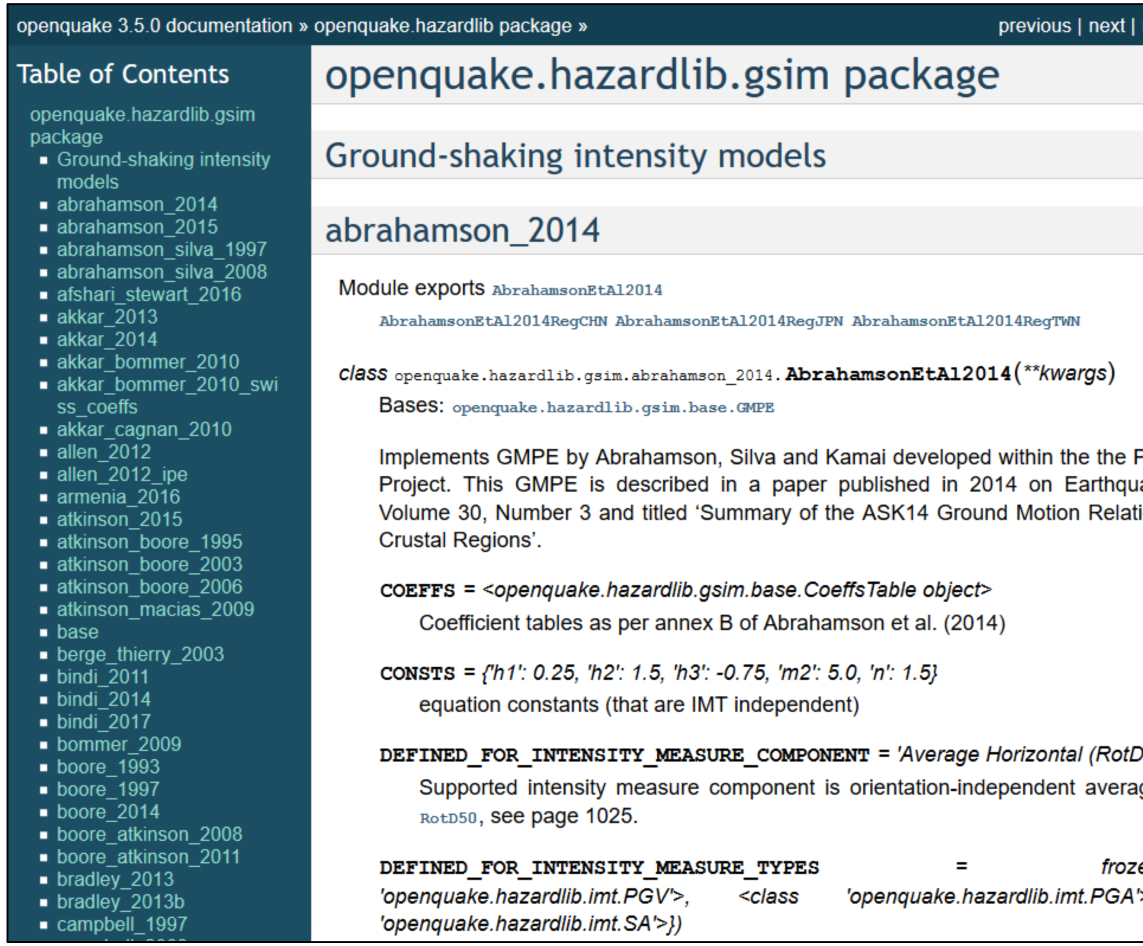

openquake 3.5.0 documentation » openquake.hazardlib package » previous | next | m

Table of Contents

openquake.hazardlib.gsim package

Ground-shaking intensity models

abrahamson_2014

Module exports `AbrahamsonEtAl2014` `AbrahamsonEtAl2014RegCHN` `AbrahamsonEtAl2014RegJPN` `AbrahamsonEtAl2014RegTWN`

class `openquake.hazardlib.gsim.abrahamson_2014.`**`AbrahamsonEtAl2014`**(***kwargs*)

Bases: `openquake.hazardlib.gsim.base.GMPE`

Implements GMPE by Abrahamson, Silva and Kamai developed within the the PE Project. This GMPE is described in a paper published in 2014 on Earthquak Volume 30, Number 3 and titled ‘Summary of the ASK14 Ground Motion Relatio Crustal Regions’.

COEFFS = *<openquake.hazardlib.gsim.base.CoeffsTable object>*

Coefficient tables as per annex B of Abrahamson et al. (2014)

CONSTS = *{'h1': 0.25, 'h2': 1.5, 'h3': -0.75, 'm2': 5.0, 'n': 1.5}*

equation constants (that are IMT independent)

DEFINED_FOR_INTENSITY_MEASURE_COMPONENT = *'Average Horizontal (RotD5*

Supported intensity measure component is orientation-independent average `RotD50`, see page 1025.

DEFINED_FOR_INTENSITY_MEASURE_TYPES = *frozen* *'openquake.hazardlib.imt.PGV'>, <class 'openquake.hazardlib.imt.PGA'>, 'openquake.hazardlib.imt.SA'>})*

To access the GMPE Library go to: https://docs.openquake.org/oq-engine/master/openquake.hazardlib.gsim.html

Example: Bindi et al., 2011

Name →

Description →

Tectonic region →

bindi_2011

Module exports `BindiEtAl2011`.

class `openquake.hazardlib.gsim.bindi_2011.`**`BindiEtAl2011`**(***kwargs*) [source]

Bases: `openquake.hazardlib.gsim.base.GMPE`

Implements GMPE developed by D.Bindi, F.Pacor, L.Luzi, R.Puglia, M.Massa, G. Ameri, R. Paolucci and published as “Ground motion prediction equations derived from the Italian strong motion data”, Bull Earthquake Eng, DOI 10.1007/s10518-011-9313-z. SA are given up to 2 s. The regressions are developed considering the geometrical mean of the as-recorded horizontal components

COEFFS = *<openquake.hazardlib.gsim.base.CoeffsTable object>*

DEFINED_FOR_INTENSITY_MEASURE_COMPONENT = *'Average horizontal'*

Supported intensity measure component is the geometric mean of two horizontal components

DEFINED_FOR_INTENSITY_MEASURE_TYPES = *frozenset({<class 'openquake.hazardlib.imt.PGA'>, <class 'openquake.hazardlib.imt.SA'>, <class 'openquake.hazardlib.imt.PGV'>})*

Set of `intensity measure types` this GSIM can calculate. A set should contain classes from module `openquake.hazardlib.imt`.

DEFINED_FOR_STANDARD_DEVIATION_TYPES = *frozenset({'Inter event', 'Intra event', 'Total'})*

Supported standard deviation types are inter-event, intra-event and total, page 1904

DEFINED_FOR_TECTONIC_REGION_TYPE = *'Active Shallow Crust'*

Supported tectonic region type is ‘active shallow crust’ because the equations have been derived from data from Italian database ITACA, as explained in the ‘Introduction’.

REQUIRES_DISTANCES = *frozenset({'rjb'})*

Required distance measure is RRup (eq. 1).

REQUIRES_RUPTURE_PARAMETERS = *frozenset({'mag', 'rake'})*

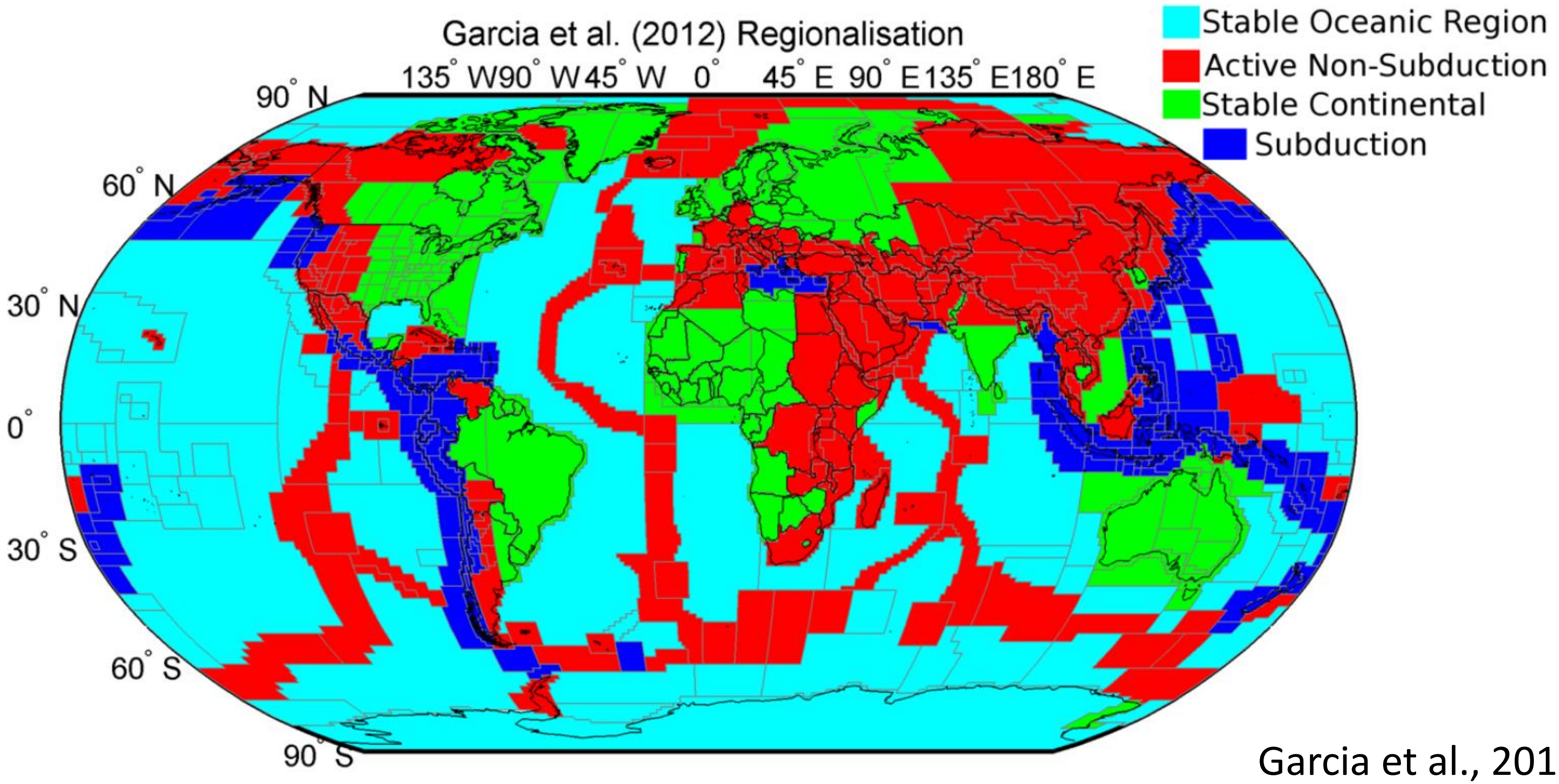
Required rupture parameters are magnitude and rake (eq. 1).

REQUIRES_SITES_PARAMETERS = *frozenset({'vs30'})*

Required site parameter is only Vs30

Tectonic Regionalization

Which tectonic region is your study area ?

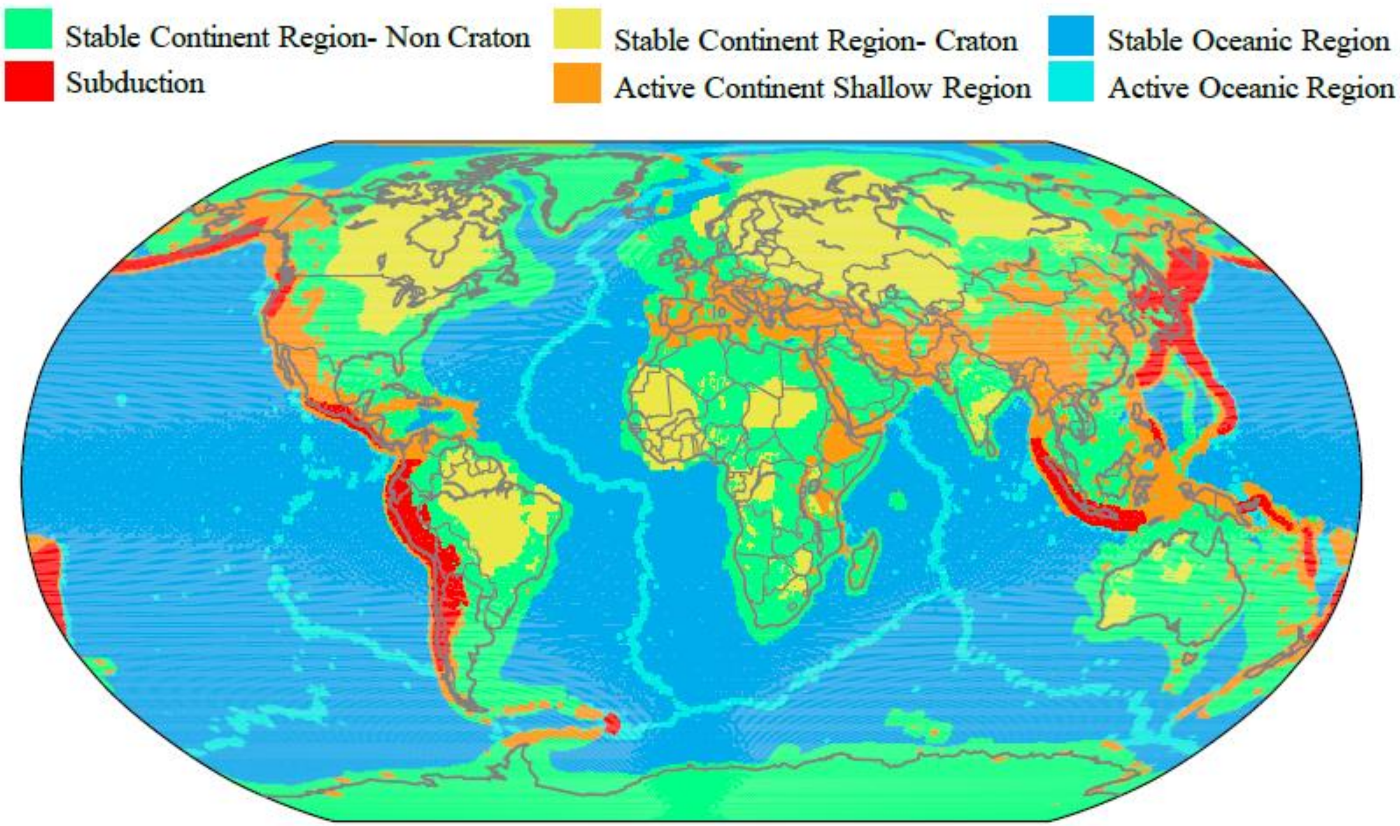


Garcia et al., 2012

Tectonic Regionalization

Which tectonic region is your study area ?

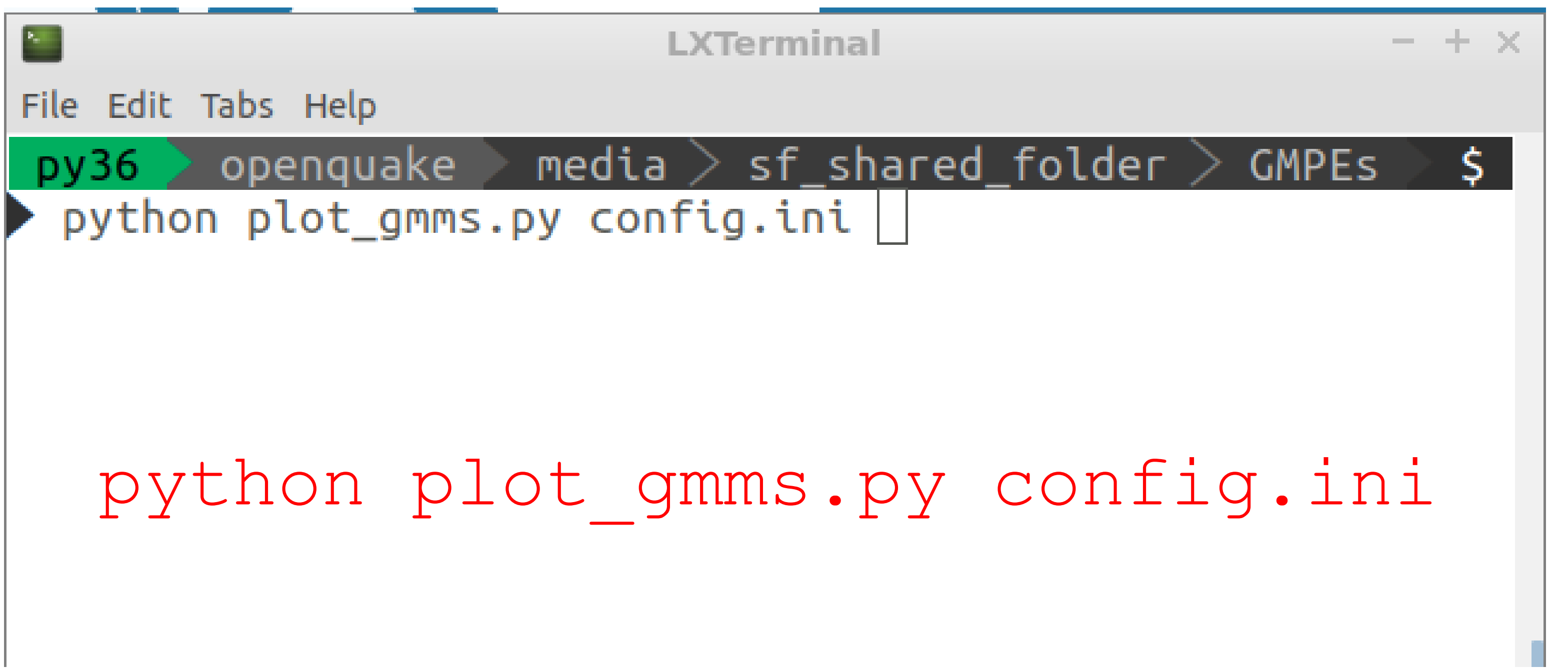
A transparent and data-driven global tectonic regionalisation model for seismic hazard assessment



Chen et al., 2018

Python script for Plotting Selected GMPEs

- plot_gmms.py
- config.ini (specify GMPEs, IMTLs, magnitude)



Example

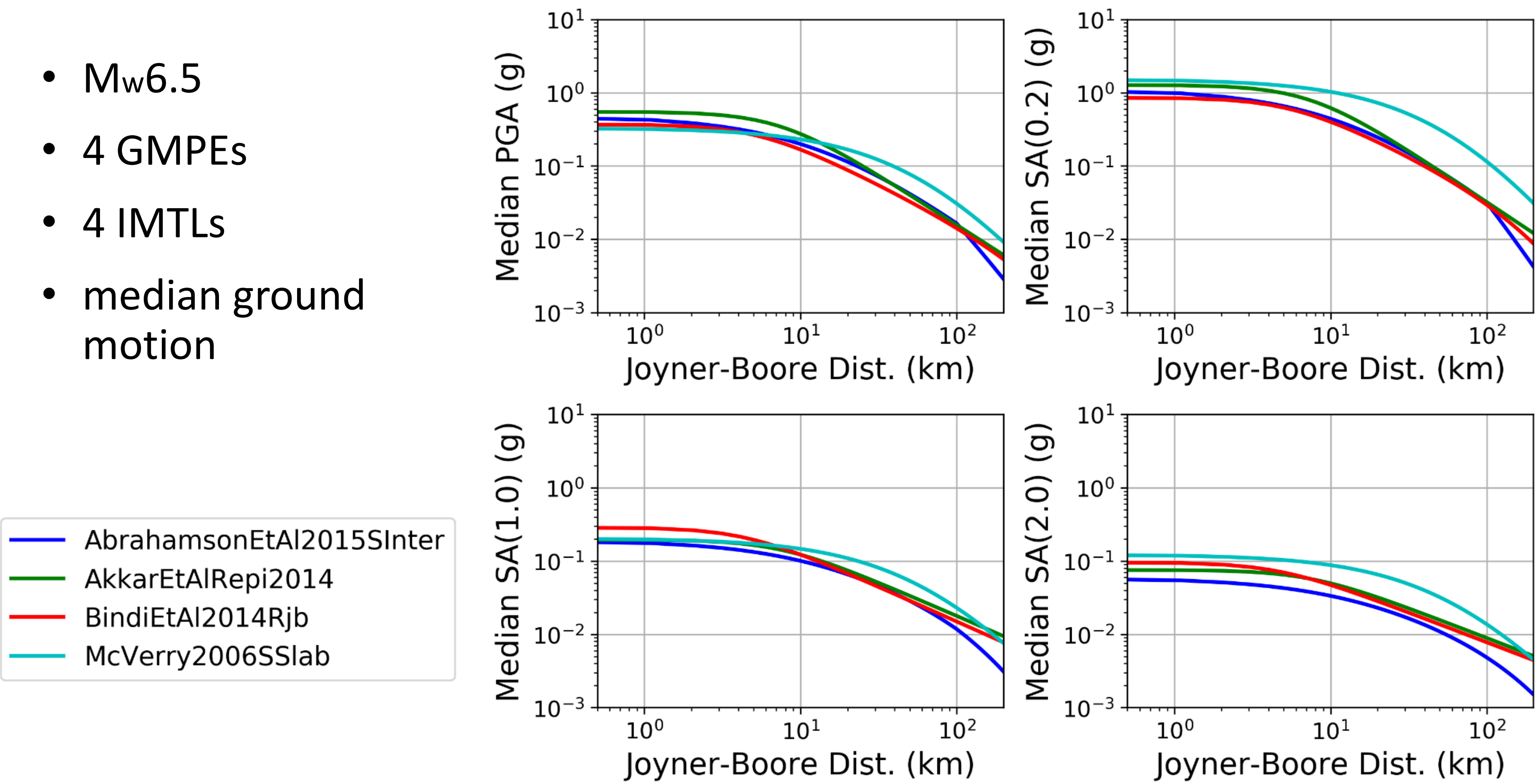
```
[general]
gmpe_list = [AbrahamsonEtAl2015SInter, AkkarEtAlRepi2014, BindiEtAl2014Rjb, McVerry2006SSlab]

#recommend using four or fewer IMTs
imt_list = [PGA, SA(0.2), SA(1.0), SA(2.0)]

[rupture]
#rupture magnitude
magnitude = 6.5
```

config.ini

- Mw6.5
- 4 GMPEs
- 4 IMTLs
- median ground motion



Compare to GMPE(s) used in publication

For all groups, either attenuation plots or equations are given

Turkey

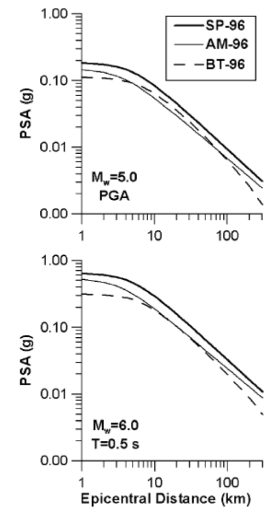
Table 5 Attenuation relationships employed in the study

Reference	σ	Empirical form of the relationship
Joyner and Boore (1988)	0.26	$\log PGA = 0.43 + 0.23(M_s - 6) - \log(r) - 0.0027(r)$
Gülkan and Kalkan (2002)	0.562	$\ln PGA = -0.682 + 0.258(M_w - 6) + 0.036(M_w - 6)^2 - 0.562\ln(r)\ 0.297\ln(V_S/V_A)$ $r = \sqrt{r_{cl}^2 + h^2}\ V_A = 1{,}381$ and $h = 4.48$
Ulusay et al. (2004)	0.63	$PGA = 2.18e^{(0.0218(33.3M_w - Re + 7.8427SA + 18.9282SB)}$ SA:0, SB:0 (rock), SA:1, SB:0 (Soil) and SA:0, SB:1 (soft soil)
Beyaz (2004)	0.712	$\log PGA = 2.581 + (2.9 \times 10^{-2} \times (M_w)^2) - (1.305 \times \mathrm{Log}(r + 7))$

PGA the peak ground acceleration, M_s, M_w magnitudes, r epicentral distance, σ standard deviation

Spain

Fig. 6 Comparison among Sabetta and Pugliese (1996; SP-96), Ambraseys et al. (1996; AM-96), and Berge-Thierry et al. (2003; BT-03) ground motion attenuation relationships on rock conditions, for two different magnitudes and for all the vibration periods considered in the hazard calculations. Magnitude scales and distance parameters were converted to moment magnitude and epicentral distance, respectively



Ethiopia

relations as it suits the region of interest (Douglas et al., 2009). As a result, we adopted Chiou and Youngs (2008) attenuation model in our study which is one of the NGA (Next Generation of Attenuation)

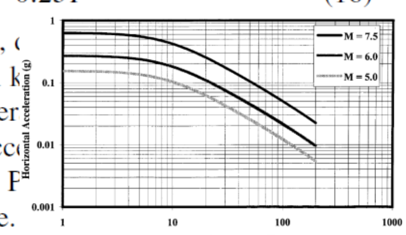
Lebanon

is used (Figure 10). This equation is given as follows:

$$Log(a_h) = -1.06 + 0.245M_w - 0.00045r$$

$$-1.0161Log(r) + 0.25P \qquad (16)$$

Where: $r^2 = d^2 + h^2$, (
h is the focal depth in k
rizontal ground acceler
of the gravitational acc
wave magnitude, and F
and 1 for 84-percentile.

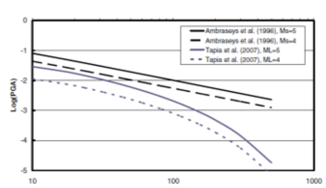


Pyrenees

Table 6 Coefficients of $\log_{10}(A) = C_1 + C_2M_L + C_3\log_{10}r + C_4r \pm \sigma$ corresponding to the ground-motion prediction equations of Tapia et al. (2007) for PGA and SA and for a depth of 10 km

T(s) (h_0=10 km)	Freq (Hz)	$C_1(f)$	$C_2(f)$	$C_3(Z)$	$C_4(f)$	σ
0.0 (PGA)	34.00	0.6	0.41	−1.0	−0.0034	0.462
0.1	10.00	1.1	0.35	−1.0	−0.0033	0.438
0.3	3.33	−0.9	0.73	−1.0	−0.0023	0.457
0.6	1.67	−2.5	0.99	−1.0	−0.0015	0.532
1.0	1.00	−3.3	1.06	−1.0	−0.0011	0.576
2.0	0.50	−3.9	1.05	−1.0	−0.0004	0.577

Acceleration A is expressed in g.



Overwhelmed by all the GMPEs?

Here is a list of some of the most commonly used GMPEs **coming from ALL tectonic regions**

Use this list as a starting point for selecting your GMPEs

In parentheses are the names used for OQ input

abrahamson_2015 (AbrahamsonEtAl2015SInter, AbrahamsonEtAl2015SSlab)
abrahamson_silva_2008 (AbrahamsonSilva2008)
akkar_2014 (AkkarEtAlRepi2014, AkkarEtAlRhyp2014, AkkarEtAlRjb2014)
akkar_bommer_2010 (AkkarBommer2010)
atkinson_boore_2006 (AtkinsonBoore2006)
bindi_2011 (BindiEtAl2011)
bindi_2014 (BindiEtAl2014Rhyp, BindiEtAl2014Rjb, BindiEtAl2014RjbEC8)
boore_2014 (BooreEtAl2014)
boore_atkinson_2008 (BooreAtkinson2008)
boore_atkinson_2011 (BooreAtkinson2011)
campbell_bozorgnia_2008 (CampbellBozorgnia2008)
campbell_bozorgnia_2014 (CampbellBozorgnia2014)
cauzzi_2014 (CauzziEtAl2014)
chiou_youngs_2008 (ChiouYoungs2008)
chiou_youngs_2014 (ChiouYoungs2014)
faccioli_2010 (FaccioliEtAl2010)
lin_lee_2008 (LinLee2008SInter, LinLee2008SSlab)
mcverry_2006 (McVerry2006Asc, McVerry2006SInter, McVerry2006SSlab)
pezeshk_2011 (PezeshkEtAl2011)
toro_2002 (ToroEtAl2002)
youngs_1997 (YoungsEtAl1997SInter, YoungsEtAl1997SSlab)
zhao_2006 (ZhaoEtAl2006Asc, ZhaoEtAl2006SInter, ZhaoEtAl2006SSlab)

References

- Bommer JJ, Douglas J, Scherbaum F, Cotton F, Bungum H, Fäh D (2010b) On the selection of ground-motion prediction equations for seismic hazard analysis. Seismol Res Lett 81:783–793

- Chen, Y-S, Weatherill, G, Pagani, M, Cotton, F. (2018). A transparent and data-driven global tectonic regionalization model for seismic hazard assessment. Geophysical Journal International. 213. 10.1093/gji/ggy005.

- Cotton, F., Scherbaum, F., Bommer, J. J. and Bungum, H., 2006. Criteria for selecting and adjusting ground-motion models for specific target regions: Application to central Europe and rock sites, J. Seism., 10:2, 137-156.

- Garcia, D., Wald, D., & Hearne, M., 2012. A Global Earthquake Discrimination Scheme to Optimize Ground-Motion Prediction Equation Selection, Bulletin of the Seismological Society of America, 102(1), 185{203.