CTBT: SCIENCE AND TECHNOLOGY 2017 CONFERENCE

# Development of Seismic Hazard Maps for Georgia

***Nino Sidamon Tsereteli***[1], *Aysegul Askan* [2] *Otar Varazanashvili*[1], *Viktor Alania*[1] *and Nino Kvavadze*[1],

***(1)M. Nodia Institute of Geophysics of I. Javakhishvili Tbilisi State University, Tbilisi, Georgia***

***(2) Departments of Civil Engineering and Earthquake Studies, Middle East Technical University, Ankara, Turkey***

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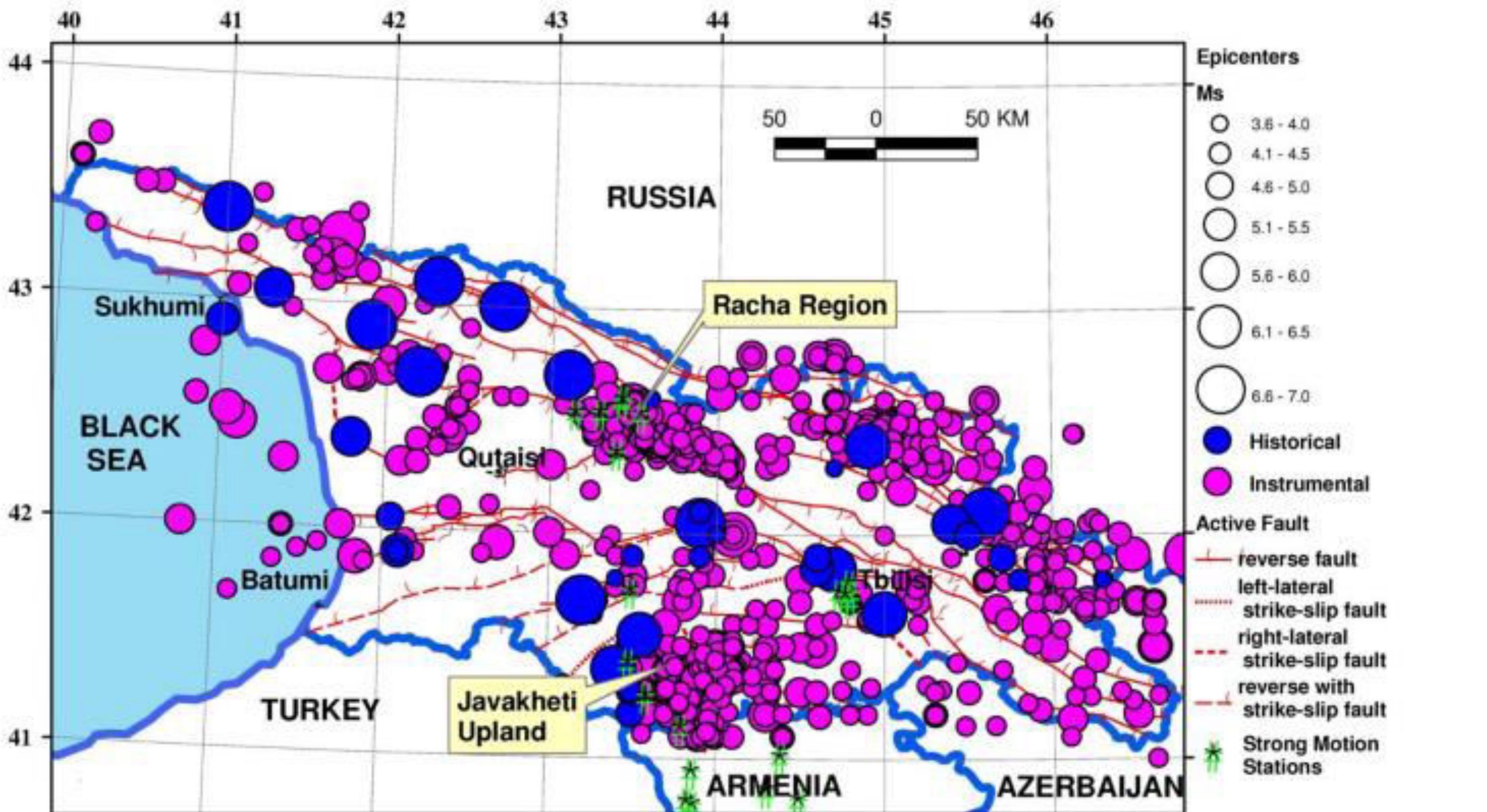
**Vienna, Austria**



40
41
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Epicenters
Ms
3.6 - 4.0
4.1 - 4.5
4.6 - 5.0
5.1 - 5.5
5.6 - 6.0
6.1 - 6.5
6.6 - 7.0
Historical
Instrumental
Active Fault
reverse fault
left-lateral strike-slip fault
right-lateral strike-slip fault
reverse with strike-slip fault
Strong Motion Stations
50
0
50 KM
RUSSIA
Racha Region
Sukhumi
BLACK SEA
Qutaisi
Batumi
Tbilisi
Javakheti Upland
TURKEY
ARMENIA
AZERBAIJAN

In this work PSHA is performed for Georgia by improved version of the standard methodology developed in the frame of EMME project.
A basic aspect of this new approach is to use hybrid empirical ground motion prediction equations developed for PGA and SA at selected periods.

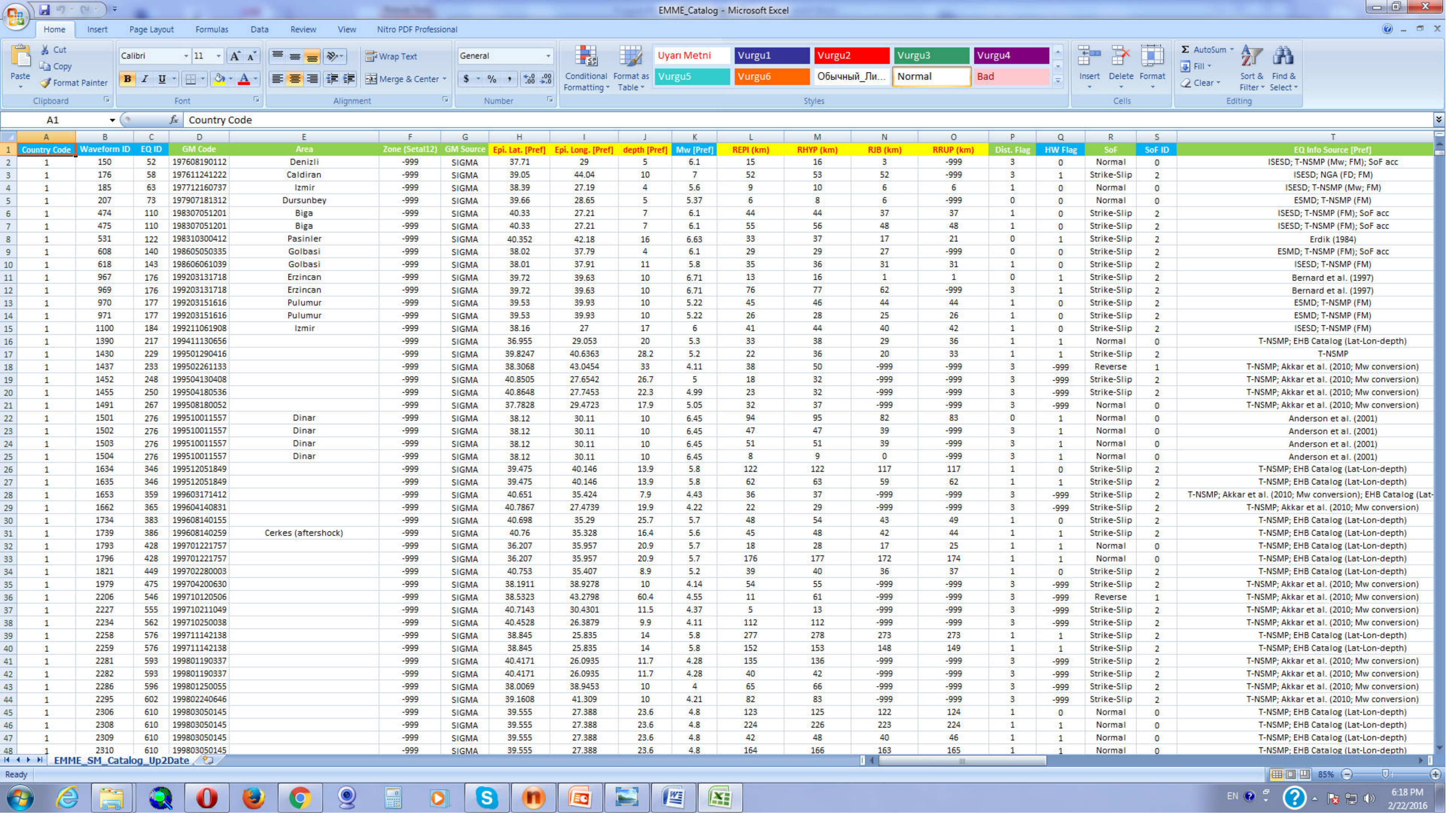
Ground motion prediction equations are essential for several purposes ranging from seismic design and analysis to probabilistic seismic hazard assessment.

In seismically active regions without sufficient strong motion data to build empirical models, hybrid models become vital.

Georgia does not have sufficient strong ground motion data to build empirical ground motion models. In this study, we have applied the host-to-target method in two regions in Georgia with different source mechanisms.

## Crustal events

1. Turkey
2. Iran out of Zagros)
3. Caucasus (Georgia & Armenia).
4. Jordan

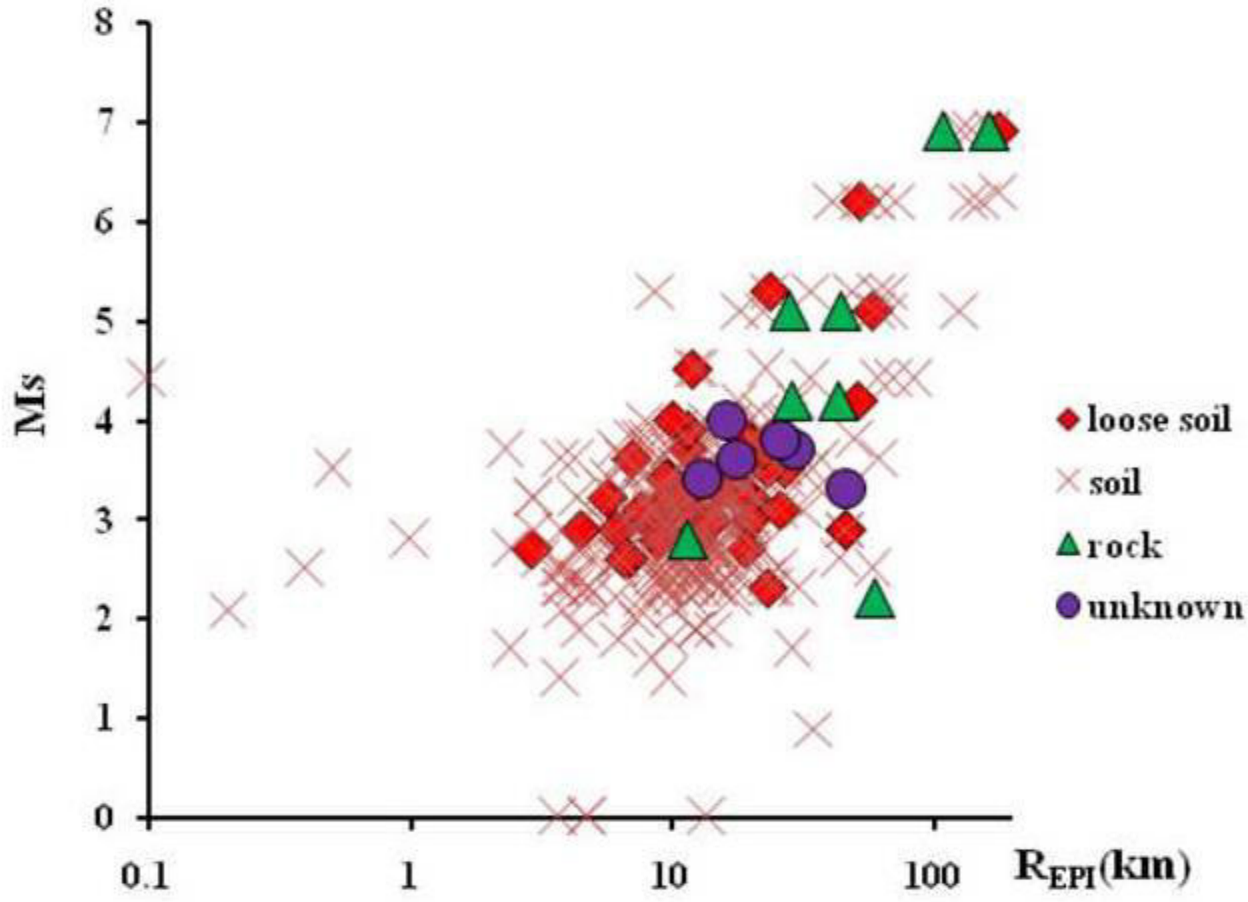


EMME_Catalog - Microsoft Excel

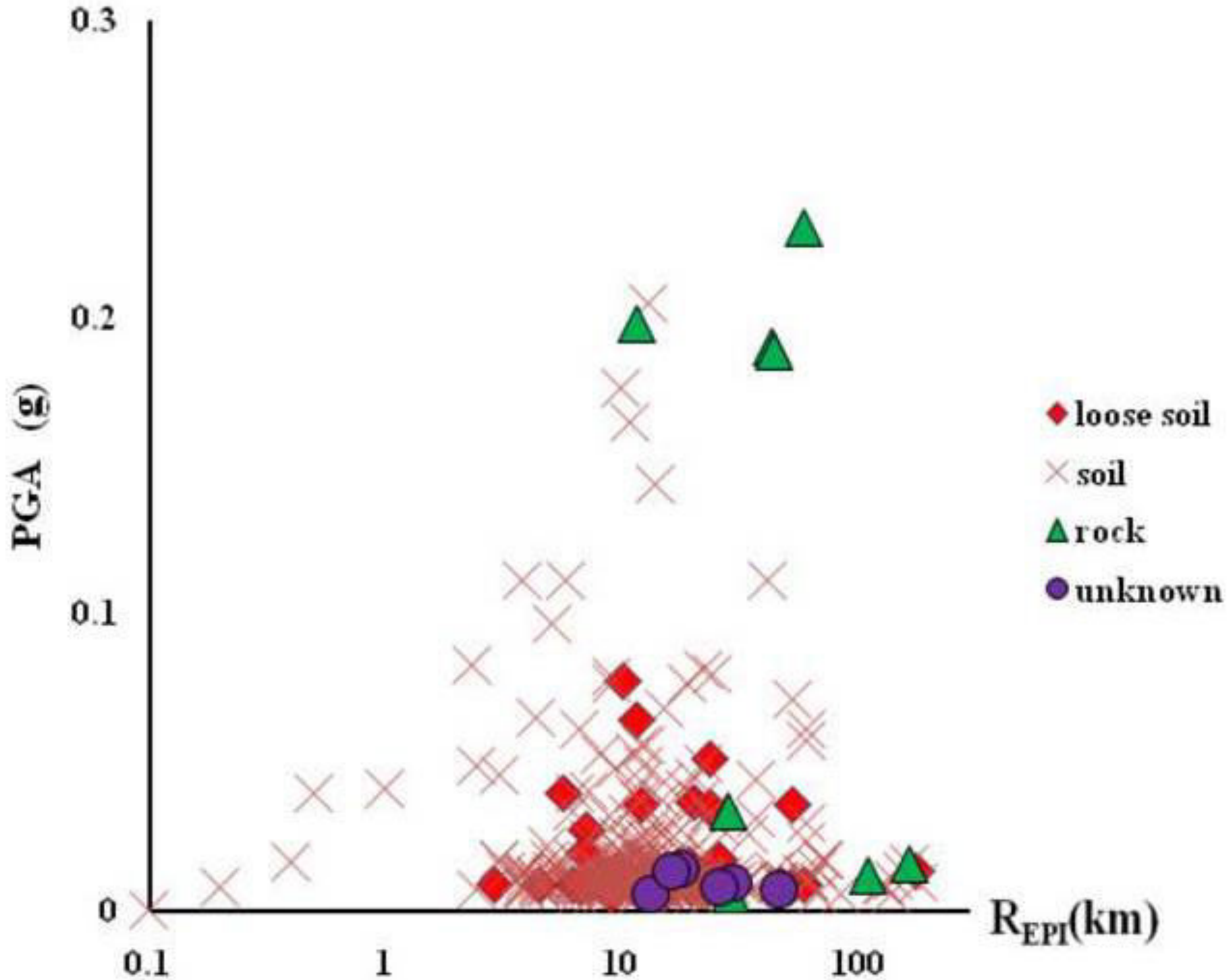
| Country Code | Waveform ID | EQ ID | GM Code | Area | Zone (Setal12) | GM Source | Epi. Lat. [Pref] | Epi. Long. [Pref] | depth [Pref] | Mw [Pref] | REPI (km) | RHYP (km) | RJB (km) | RRUP (km) | Dist. Flag | HW Flag | SoF | SoF ID | EQ Info Source [Pref] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 150 | 52 | 197608190112 | Denizli | -999 | SIGMA | 37.71 | 29 | 5 | 6.1 | 15 | 16 | 3 | -999 | 3 | 0 | Normal | 0 | ISESD; T-NSMP (Mw; FM); SoF acc |
| 1 | 176 | 58 | 197611241222 | Caldiran | -999 | SIGMA | 39.05 | 44.04 | 10 | 7 | 52 | 53 | 52 | -999 | 3 | 1 | Strike-Slip | 2 | ISESD; NGA (FD; FM) |
| 1 | 185 | 63 | 197712160737 | Izmir | -999 | SIGMA | 38.39 | 27.19 | 4 | 5.6 | 9 | 10 | 6 | 6 | 1 | 0 | Normal | 0 | ISESD; T-NSMP (Mw; FM) |
| 1 | 207 | 73 | 197907181312 | Dursunbey | -999 | SIGMA | 39.66 | 28.65 | 5 | 5.37 | 6 | 8 | 6 | -999 | 0 | 0 | Normal | 0 | ESMD; T-NSMP (FM) |
| 1 | 474 | 110 | 198307051201 | Biga | -999 | SIGMA | 40.33 | 27.21 | 7 | 6.1 | 44 | 44 | 37 | 37 | 1 | 0 | Strike-Slip | 2 | ISESD; T-NSMP (FM); SoF acc |
| 1 | 475 | 110 | 198307051201 | Biga | -999 | SIGMA | 40.33 | 27.21 | 7 | 6.1 | 55 | 56 | 48 | 48 | 1 | 0 | Strike-Slip | 2 | ISESD; T-NSMP (FM); SoF acc |
| 1 | 531 | 122 | 198310300412 | Pasinler | -999 | SIGMA | 40.352 | 42.18 | 16 | 6.63 | 33 | 37 | 17 | 21 | 0 | 1 | Strike-Slip | 2 | Erdik (1984) |
| 1 | 608 | 140 | 198605050335 | Golbasi | -999 | SIGMA | 38.02 | 37.79 | 4 | 6.1 | 29 | 29 | 27 | -999 | 0 | 0 | Strike-Slip | 2 | ESMD; T-NSMP (FM); SoF acc |
| 1 | 618 | 143 | 198606061039 | Golbasi | -999 | SIGMA | 38.01 | 37.91 | 11 | 5.8 | 35 | 36 | 31 | 31 | 1 | 0 | Strike-Slip | 2 | ISESD; T-NSMP (FM) |
| 1 | 967 | 176 | 199203131718 | Erzincan | -999 | SIGMA | 39.72 | 39.63 | 10 | 6.71 | 13 | 16 | 1 | 1 | 0 | 1 | Strike-Slip | 2 | Bernard et al. (1997) |
| 1 | 969 | 176 | 199203131718 | Erzincan | -999 | SIGMA | 39.72 | 39.63 | 10 | 6.71 | 76 | 77 | 62 | -999 | 3 | 1 | Strike-Slip | 2 | Bernard et al. (1997) |
| 1 | 970 | 177 | 199203151616 | Pulumur | -999 | SIGMA | 39.53 | 39.93 | 10 | 5.22 | 45 | 46 | 44 | 44 | 1 | 0 | Strike-Slip | 2 | ESMD; T-NSMP (FM) |
| 1 | 971 | 177 | 199203151616 | Pulumur | -999 | SIGMA | 39.53 | 39.93 | 10 | 5.22 | 26 | 28 | 25 | 26 | 1 | 0 | Strike-Slip | 2 | ESMD; T-NSMP (FM) |
| 1 | 1100 | 184 | 199211061908 | Izmir | -999 | SIGMA | 38.16 | 27 | 17 | 6 | 41 | 44 | 40 | 42 | 1 | 0 | Strike-Slip | 2 | ISESD; T-NSMP (FM) |
| 1 | 1390 | 217 | 199411130656 | | -999 | SIGMA | 36.955 | 29.053 | 20 | 5.3 | 33 | 38 | 29 | 36 | 1 | 1 | Normal | 0 | T-NSMP; EHB Catalog (Lat-Lon-depth) |
| 1 | 1430 | 229 | 199501290416 | | -999 | SIGMA | 39.8247 | 40.6363 | 28.2 | 5.2 | 22 | 36 | 20 | 33 | 1 | 1 | Strike-Slip | 2 | T-NSMP |
| 1 | 1437 | 233 | 199502261133 | | -999 | SIGMA | 38.3068 | 43.0454 | 33 | 4.11 | 38 | 50 | -999 | -999 | 3 | -999 | Reverse | 1 | T-NSMP; Akkar et al. (2010; Mw conversion) |
| 1 | 1452 | 248 | 199504130408 | | -999 | SIGMA | 40.8505 | 27.6542 | 26.7 | 5 | 18 | 32 | -999 | -999 | 3 | -999 | Strike-Slip | 2 | T-NSMP; Akkar et al. (2010; Mw conversion) |
| 1 | 1455 | 250 | 199504180536 | | -999 | SIGMA | 40.8648 | 27.7453 | 22.3 | 4.99 | 23 | 32 | -999 | -999 | 3 | -999 | Strike-Slip | 2 | T-NSMP; Akkar et al. (2010; Mw conversion) |
| 1 | 1491 | 267 | 199508180052 | | -999 | SIGMA | 37.7828 | 29.4723 | 17.9 | 5.05 | 32 | 37 | -999 | -999 | 3 | -999 | Normal | 0 | T-NSMP; Akkar et al. (2010; Mw conversion) |
| 1 | 1501 | 276 | 199510011557 | Dinar | -999 | SIGMA | 38.12 | 30.11 | 10 | 6.45 | 94 | 95 | 82 | 83 | 0 | 1 | Normal | 0 | Anderson et al. (2001) |
| 1 | 1502 | 276 | 199510011557 | Dinar | -999 | SIGMA | 38.12 | 30.11 | 10 | 6.45 | 47 | 47 | 39 | -999 | 3 | 1 | Normal | 0 | Anderson et al. (2001) |
| 1 | 1503 | 276 | 199510011557 | Dinar | -999 | SIGMA | 38.12 | 30.11 | 10 | 6.45 | 51 | 51 | 39 | -999 | 3 | 1 | Normal | 0 | Anderson et al. (2001) |
| 1 | 1504 | 276 | 199510011557 | Dinar | -999 | SIGMA | 38.12 | 30.11 | 10 | 6.45 | 8 | 9 | 0 | -999 | 3 | 1 | Normal | 0 | Anderson et al. (2001) |
| 1 | 1634 | 346 | 199512051849 | | -999 | SIGMA | 39.475 | 40.146 | 13.9 | 5.8 | 122 | 122 | 117 | 117 | 1 | 0 | Strike-Slip | 2 | T-NSMP; EHB Catalog (Lat-Lon-depth) |
| 1 | 1635 | 346 | 199512051849 | | -999 | SIGMA | 39.475 | 40.146 | 13.9 | 5.8 | 62 | 63 | 59 | 62 | 1 | 1 | Strike-Slip | 2 | T-NSMP; EHB Catalog (Lat-Lon-depth) |
| 1 | 1653 | 359 | 199603171412 | | -999 | SIGMA | 40.651 | 35.424 | 7.9 | 4.43 | 36 | 37 | -999 | -999 | 3 | -999 | Strike-Slip | 2 | T-NSMP; Akkar et al. (2010; Mw conversion); EHB Catalog (Lat- |
| 1 | 1662 | 365 | 199604140831 | | -999 | SIGMA | 40.7867 | 27.4739 | 19.9 | 4.22 | 22 | 29 | -999 | -999 | 3 | -999 | Strike-Slip | 2 | T-NSMP; Akkar et al. (2010; Mw conversion) |
| 1 | 1734 | 383 | 199608140155 | | -999 | SIGMA | 40.698 | 35.29 | 25.7 | 5.7 | 48 | 54 | 43 | 49 | 1 | 0 | Strike-Slip | 2 | T-NSMP; EHB Catalog (Lat-Lon-depth) |
| 1 | 1739 | 386 | 199608140259 | Cerkes (aftershock) | -999 | SIGMA | 40.76 | 35.328 | 16.4 | 5.6 | 45 | 48 | 42 | 44 | 1 | 1 | Strike-Slip | 2 | T-NSMP; EHB Catalog (Lat-Lon-depth) |
| 1 | 1793 | 428 | 199701221757 | | -999 | SIGMA | 36.207 | 35.957 | 20.9 | 5.7 | 18 | 28 | 17 | 25 | 1 | 1 | Normal | 0 | T-NSMP; EHB Catalog (Lat-Lon-depth) |
| 1 | 1796 | 428 | 199701221757 | | -999 | SIGMA | 36.207 | 35.957 | 20.9 | 5.7 | 176 | 177 | 172 | 174 | 1 | 1 | Normal | 0 | T-NSMP; EHB Catalog (Lat-Lon-depth) |
| 1 | 1821 | 449 | 199702280003 | | -999 | SIGMA | 40.753 | 35.407 | 8.9 | 5.2 | 39 | 40 | 36 | 37 | 1 | 0 | Strike-Slip | 2 | T-NSMP; EHB Catalog (Lat-Lon-depth) |
| 1 | 1979 | 475 | 199704200630 | | -999 | SIGMA | 38.1911 | 38.9278 | 10 | 4.14 | 54 | 55 | -999 | -999 | 3 | -999 | Strike-Slip | 2 | T-NSMP; Akkar et al. (2010; Mw conversion) |
| 1 | 2206 | 546 | 199710120506 | | -999 | SIGMA | 38.5323 | 43.2798 | 60.4 | 4.55 | 11 | 61 | -999 | -999 | 3 | -999 | Reverse | 1 | T-NSMP; Akkar et al. (2010; Mw conversion) |
| 1 | 2227 | 555 | 199710211049 | | -999 | SIGMA | 40.7143 | 30.4301 | 11.5 | 4.37 | 5 | 13 | -999 | -999 | 3 | -999 | Strike-Slip | 2 | T-NSMP; Akkar et al. (2010; Mw conversion) |
| 1 | 2234 | 562 | 199710250038 | | -999 | SIGMA | 40.4528 | 26.3879 | 9.9 | 4.11 | 112 | 112 | -999 | -999 | 3 | -999 | Strike-Slip | 2 | T-NSMP; Akkar et al. (2010; Mw conversion) |
| 1 | 2258 | 576 | 199711142138 | | -999 | SIGMA | 38.845 | 25.835 | 14 | 5.8 | 277 | 278 | 273 | 273 | 1 | 1 | Strike-Slip | 2 | T-NSMP; EHB Catalog (Lat-Lon-depth) |
| 1 | 2259 | 576 | 199711142138 | | -999 | SIGMA | 38.845 | 25.835 | 14 | 5.8 | 152 | 153 | 148 | 149 | 1 | 1 | Strike-Slip | 2 | T-NSMP; EHB Catalog (Lat-Lon-depth) |
| 1 | 2281 | 593 | 199801190337 | | -999 | SIGMA | 40.4171 | 26.0935 | 11.7 | 4.28 | 135 | 136 | -999 | -999 | 3 | -999 | Strike-Slip | 2 | T-NSMP; Akkar et al. (2010; Mw conversion) |
| 1 | 2282 | 593 | 199801190337 | | -999 | SIGMA | 40.4171 | 26.0935 | 11.7 | 4.28 | 40 | 42 | -999 | -999 | 3 | -999 | Strike-Slip | 2 | T-NSMP; Akkar et al. (2010; Mw conversion) |
| 1 | 2286 | 596 | 199801250055 | | -999 | SIGMA | 38.0069 | 38.9453 | 10 | 4 | 65 | 66 | -999 | -999 | 3 | -999 | Strike-Slip | 2 | T-NSMP; Akkar et al. (2010; Mw conversion) |
| 1 | 2295 | 602 | 199802240646 | | -999 | SIGMA | 39.1608 | 41.309 | 10 | 4.21 | 82 | 83 | -999 | -999 | 3 | -999 | Strike-Slip | 2 | T-NSMP; Akkar et al. (2010; Mw conversion) |
| 1 | 2306 | 610 | 199803050145 | | -999 | SIGMA | 39.555 | 27.388 | 23.6 | 4.8 | 123 | 125 | 122 | 124 | 1 | 0 | Normal | 0 | T-NSMP; EHB Catalog (Lat-Lon-depth) |
| 1 | 2308 | 610 | 199803050145 | | -999 | SIGMA | 39.555 | 27.388 | 23.6 | 4.8 | 224 | 226 | 223 | 224 | 1 | 1 | Normal | 0 | T-NSMP; EHB Catalog (Lat-Lon-depth) |
| 1 | 2309 | 610 | 199803050145 | | -999 | SIGMA | 39.555 | 27.388 | 23.6 | 4.8 | 42 | 48 | 40 | 46 | 1 | 1 | Normal | 0 | T-NSMP; EHB Catalog (Lat-Lon-depth) |
| 1 | 2310 | 610 | 199803050145 | | -999 | SIGMA | 39.555 | 27.388 | 23.6 | 4.8 | 164 | 166 | 163 | 165 | 1 | 1 | Normal | 0 | T-NSMP; EHB Catalog (Lat-Lon-depth) |

EMME_SM_Catalog_Up2Date

The EMME strong-motion databank contain more that 5000 strong motion recordings with a magnitude range between 3 < Mw ≤ 7.6 and for source-to-site distances up to 400 km.



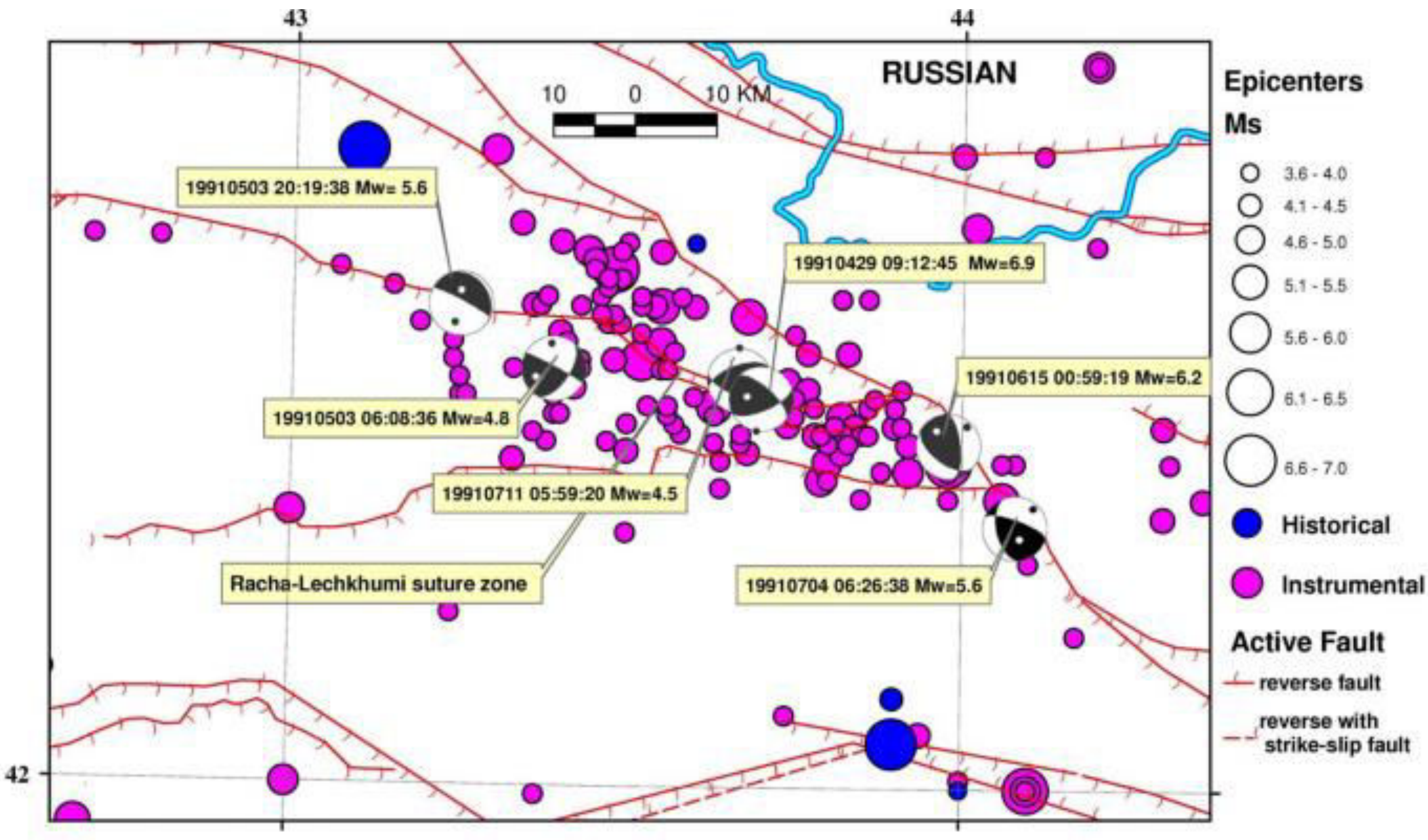
8
7
6
5
4
3
2
1
0
Ms
0.1
1
10
100
REPI(km)
loose soil
soil
rock
unknown

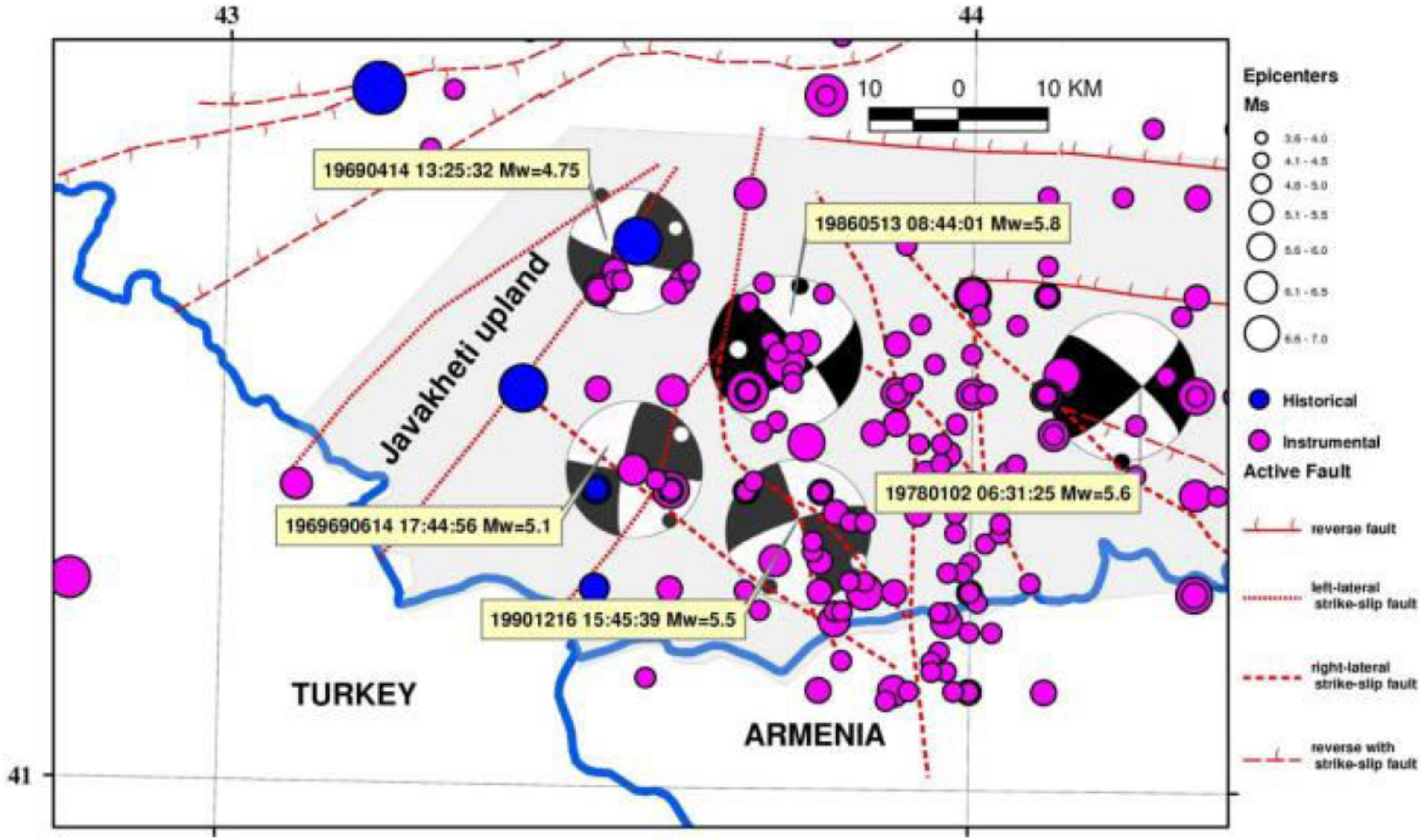


0.3
0.2
0.1
0
PGA (g)
0.1
1
10
100
$R_{EPI}$(km)
loose soil
soil
rock
unknown

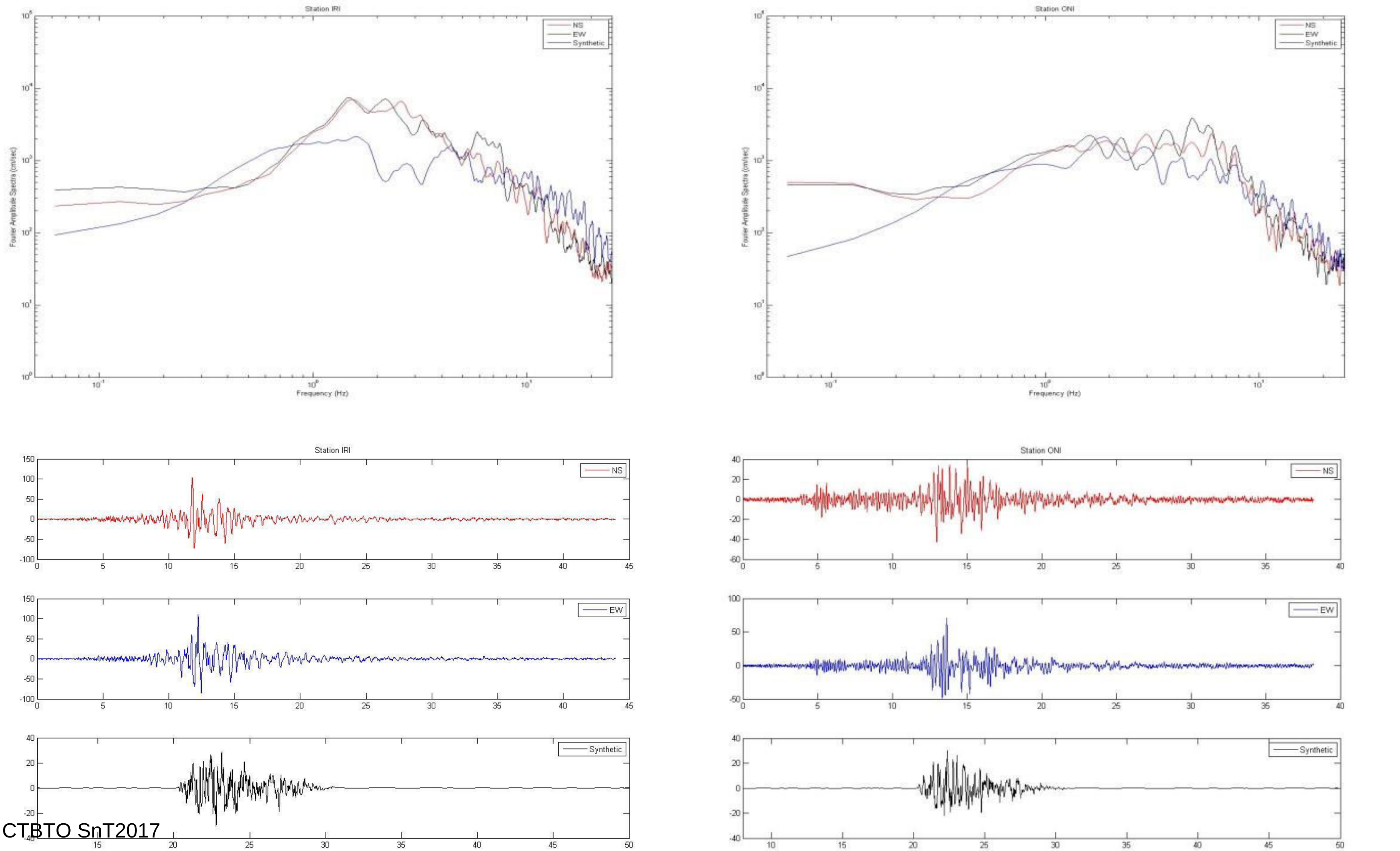
## Main Tasks for H-T Relationships

- **Identification of active fault zones in each country**
- **Definition of simulation subdomains and investigation of the seismic parameters (i.e. stress drop, fault dimensions, anelastic attenuation, geometric spreading) within these simulation subdomains**
- **Verification of regional seismic parameters through simulations of past large earthquakes**
- **For the selected range of magnitudes and distances, performing scenario simulations for both target and host regions**
- **Computing the host-to-target scale factors by scaling the simulation results.**
- **Scaling of GMPEs established for the host regions to form GMPEs for the target regions using scale factors derived in the previous step.**
- **Verification of the GMPEs formed for the target regions by validation with existing data.**

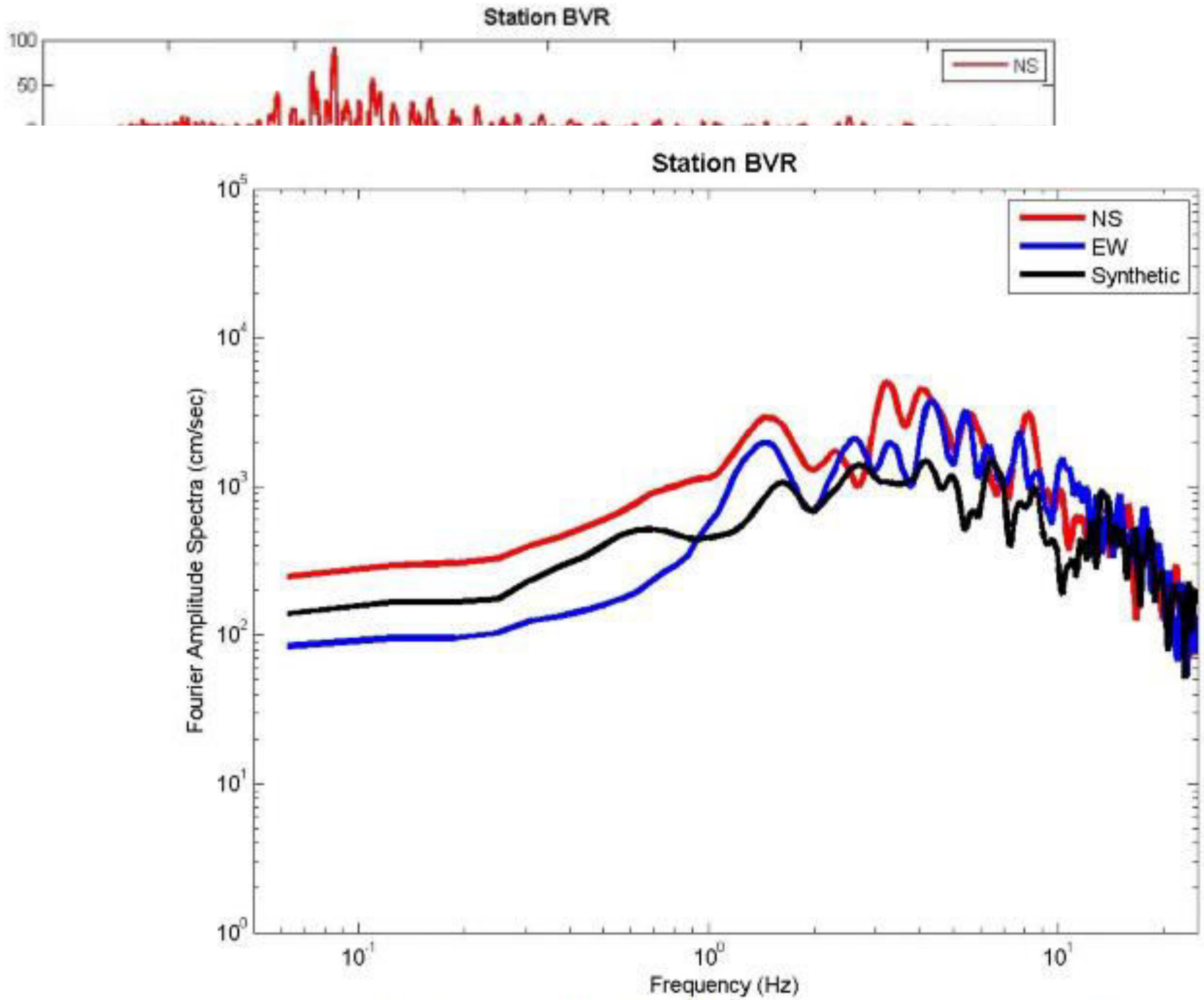

43
44
42
RUSSIAN
10 0 10 KM
19910503 20:19:38 Mw= 5.6
19910429 09:12:45 Mw=6.9
19910503 06:08:36 Mw=4.8
19910615 00:59:19 Mw=6.2
19910711 05:59:20 Mw=4.5
Racha-Lechkhumi suture zone
19910704 06:26:38 Mw=5.6
Epicenters
Ms
3.6 - 4.0
4.1 - 4.5
4.6 - 5.0
5.1 - 5.5
5.6 - 6.0
6.1 - 6.5
6.6 - 7.0
Historical
Instrumental
Active Fault
reverse fault
reverse with strike-slip fault


43
44
41
10 0 10 KM
19690414 13:25:32 Mw=4.75
19860513 08:44:01 Mw=5.8
Javakheti upland
1969690614 17:44:56 Mw=5.1
19780102 06:31:25 Mw=5.6
19901216 15:45:39 Mw=5.5
TURKEY
ARMENIA
Epicenters
Ms
3.6 - 4.0
4.1 - 4.5
4.6 - 5.0
5.1 - 5.5
5.6 - 6.0
6.1 - 6.5
6.6 - 7.0
Historical
Instrumental
Active Fault
reverse fault
left-lateral strike-slip fault
right-lateral strike-slip fault
reverse with strike-slip fault

In this study we employed finite-fault stochastic simulations based on the algorithm outlined in Motazedian and Atkinson (2005). In this step, an important point is the accuracy of input simulation parameters.



# Simulation of the 16 December 1990 Javakheti earthquake (Mw = 5.5)




Simulation results for Javakheti earthquake (16 December 1990) on BVR station. Fourier amplitude spectra.

Seismological parameters used for the scenario simulations in target regions

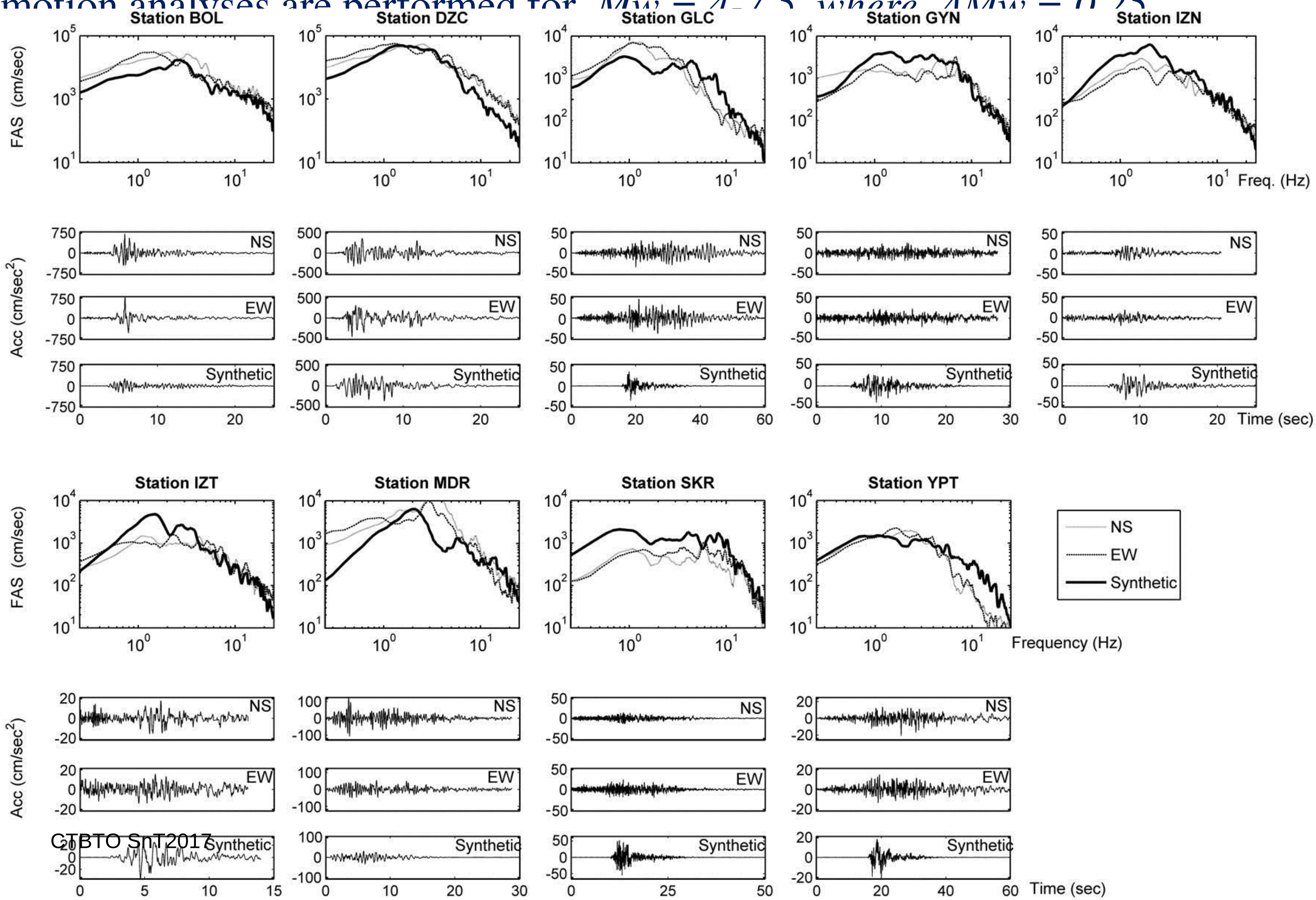
| Parameter | Racha | Javakheti |
|---|---|---|
| Magnitude-fault size relationship | Wells and Coppersmith (1994) | Wells and Coppersmith (1994) |
| Stress drop-fault size relationship | Mohammadioun and Serva (2001) | Mohammadioun and Serva (2001) |
| Geometric spreading model | | |
| 1st hinge in geometric atten. | 30.0 | 30.0 |
| 2nd hinge in geometric atten. | 100.0 | 100.0 |
| 1st slope in geometric atten. | –1.0 | –1.0 |
| 2nd slope in geometric atten. | –1 | –1 |
| 3rd slope in geometric atten. | –1 | –1 |
| $Q = Q_0 f^n$ $(Q_0, n)$ | (77, 0.937) | (37, 1.089) |
| Duration model | $T_R + 0.05\,R$ | $T_R + 0.05\,R$ |
| Kappa | 0.045 | 0.051 |
| Beta ($Vs$) [km/s] | 3.2 | 3.7 |
| Density [g/cm$^3$] | 2.7 | 2.8 |
| Rupture vel. / $S$-wave vel. | 0.8 | 0.8 |
| Window applied | Saragoni-Hart | Saragoni-Hart |
| Site amplifications | Generic rock conditions | Generic rock conditions |

Seismological parameters used for the scenario simulations in host regions

| Parameter | Tabas (Iran) | NAFZ (Turkey) |
|---|---|---|
| Magnitude-fault size relationship | Wells and Coppersmith (1994) | Wells and Coppersmith (1994) |
| Stress drop-fault size relationship | Mohammadioun and Serva (2001) | Mohammadioun and Serva (2001) |
| Geometric spreading model | | |
| 1st hinge in geometric atten. | 30.0 | 30.0 |
| 2nd hinge in geometric atten. | 100.0 | 100.0 |
| 1st slope in geometric atten. | –1.0 | –1.0 |
| 2nd slope in geometric atten. | –0.6 | –0.5 |
| 3rd slope in geometric atten. | –0.5 | –0.5 |
| $Q = Q_0 f^n$ $(Q_0, n)$ | (53, 1.02) | (122, 0.68) |
| Duration model | $T_R + 0.05\ R$ | $T_R + 0.05\ R$ |
| Kappa | 0.04 | 0.035 |
| Beta ($Vs$) [km/s] | 3.2 | 3.7 |
| Density [g/cm$^3$] | 2.7 | 2.8 |
| Rupture vel. / $S$-wave vel. | 0.8 | 0.8 |
| Window applied | Saragoni-Hart | Saragoni-Hart |
| Site amplifications | Generic rock conditions | Generic rock conditions |

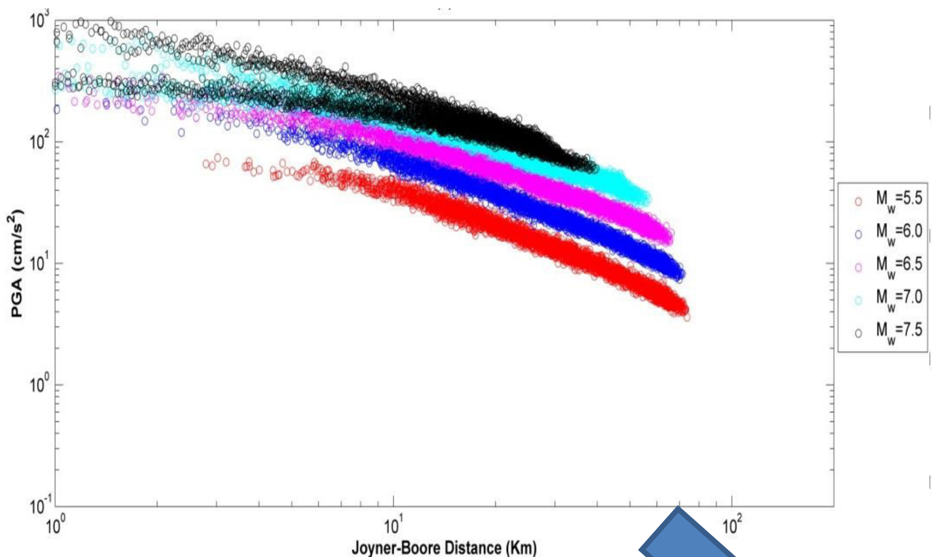
We performed ground motion simulations for a set of scenario events in both host and target regions.

The scenario set of simulations to be used in the hybrid-empirical ground motion analyses are performed for $Mw = 4\text{-}7.5$, where $\Delta Mw = 0.25$

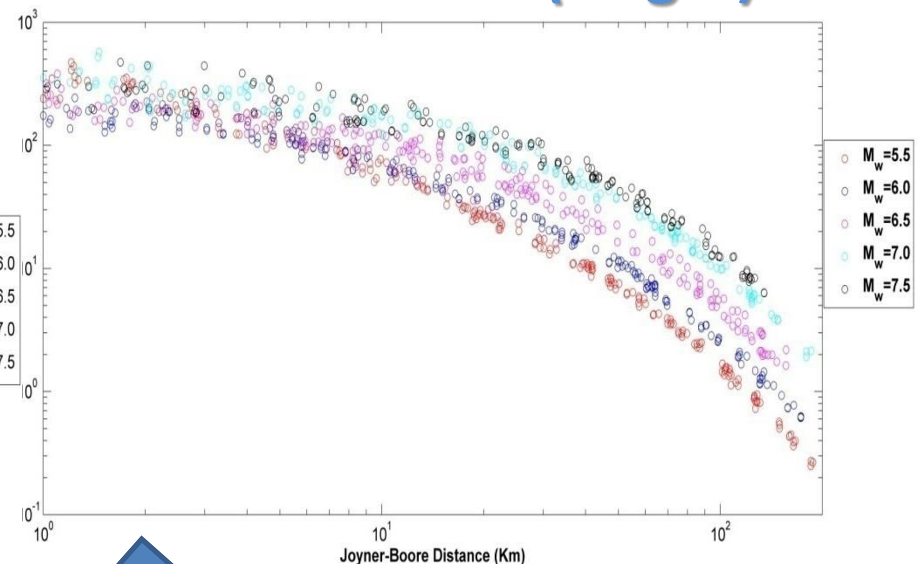


# Adjustment factors was used in the scaling of ground motion prediction equations

**DÜZCE (host)**




**GEORGIA (target)**

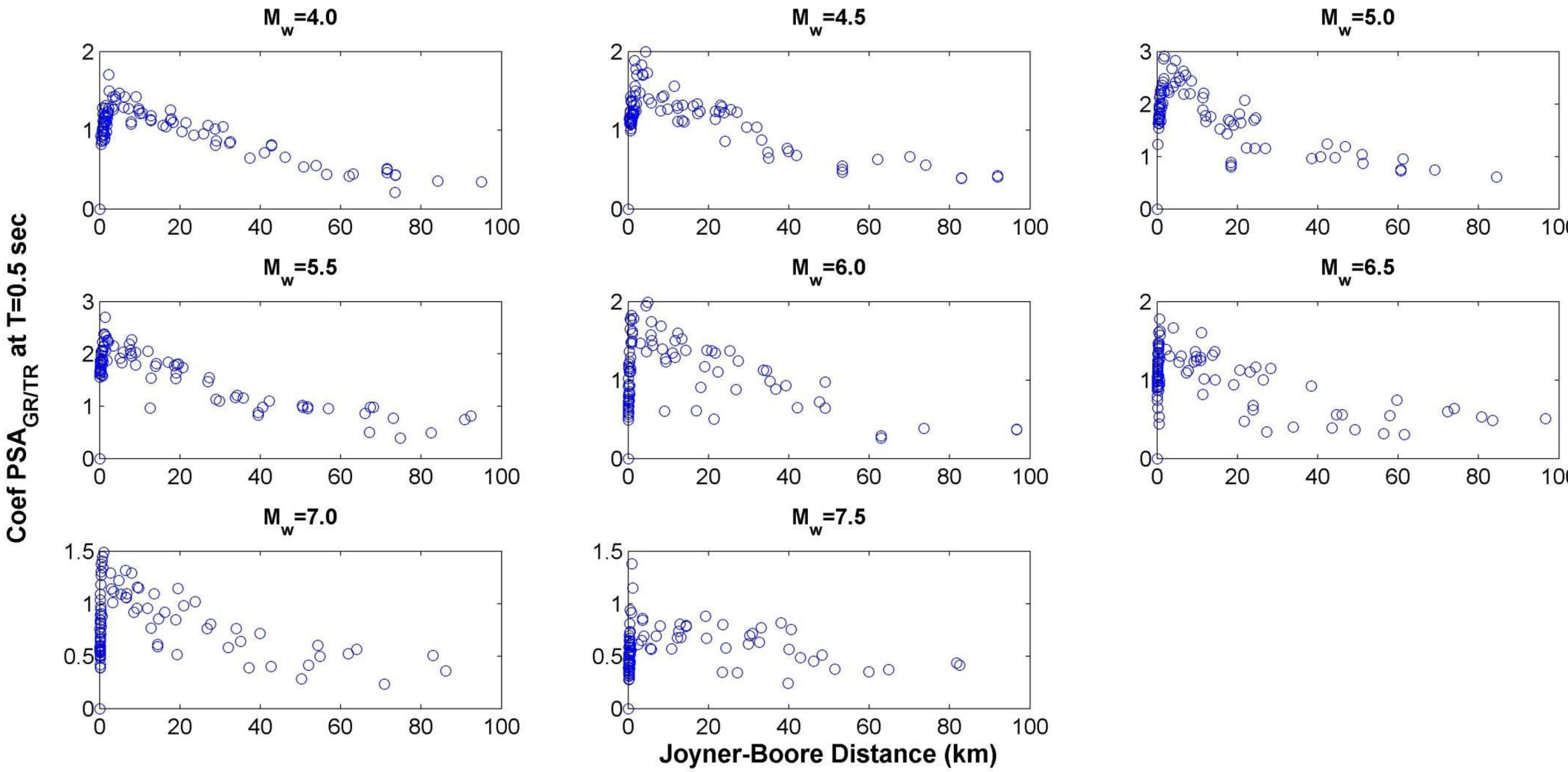



$$C_{PGA}(R) = \frac{PGA(R)_{TARGET}}{PGA(R)_{HOST}}$$

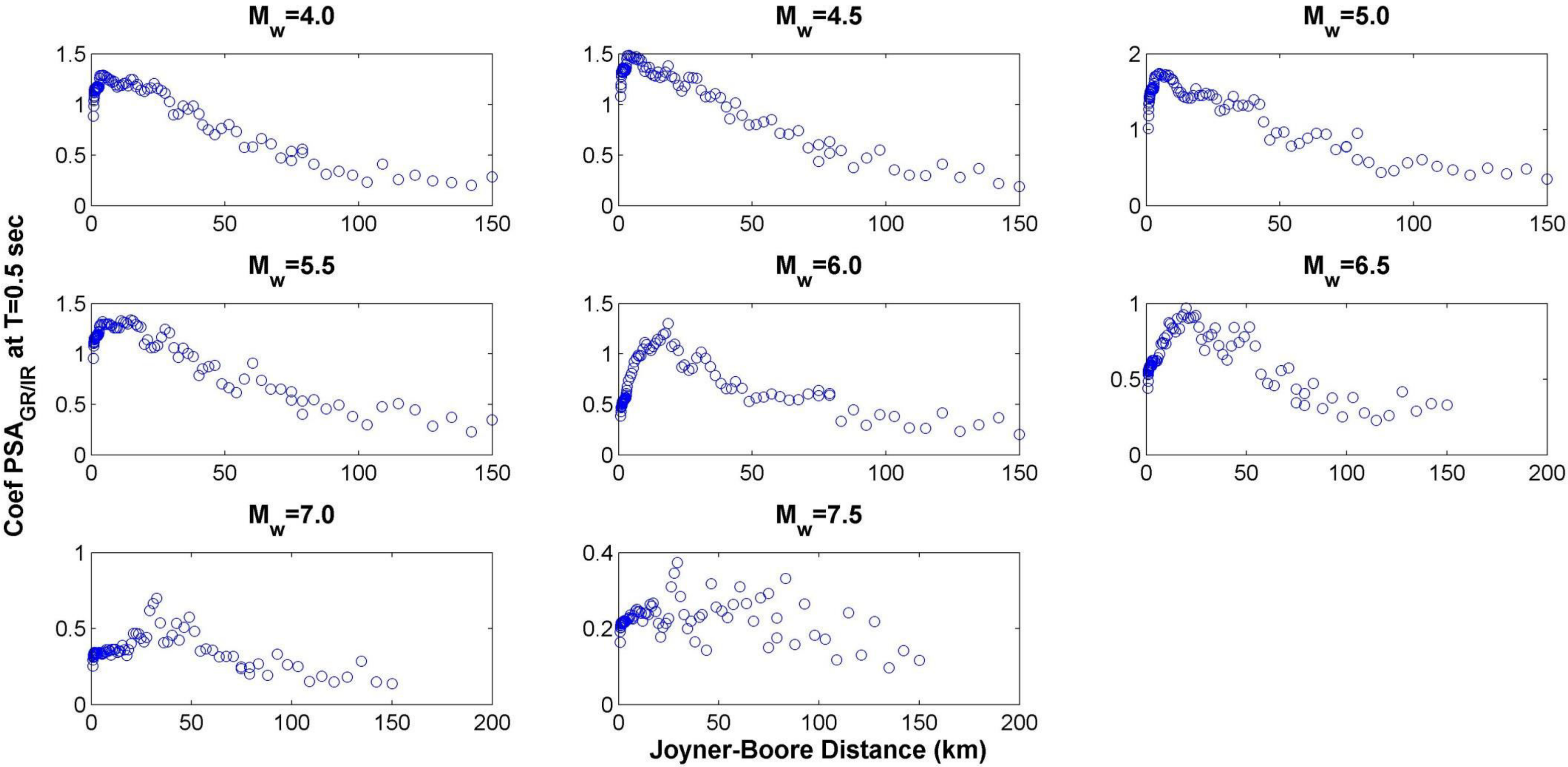
$$C_{SA}(R,T) = \frac{SA(R,T)_{TARGET}}{SA(R,T)_{HOST}}$$

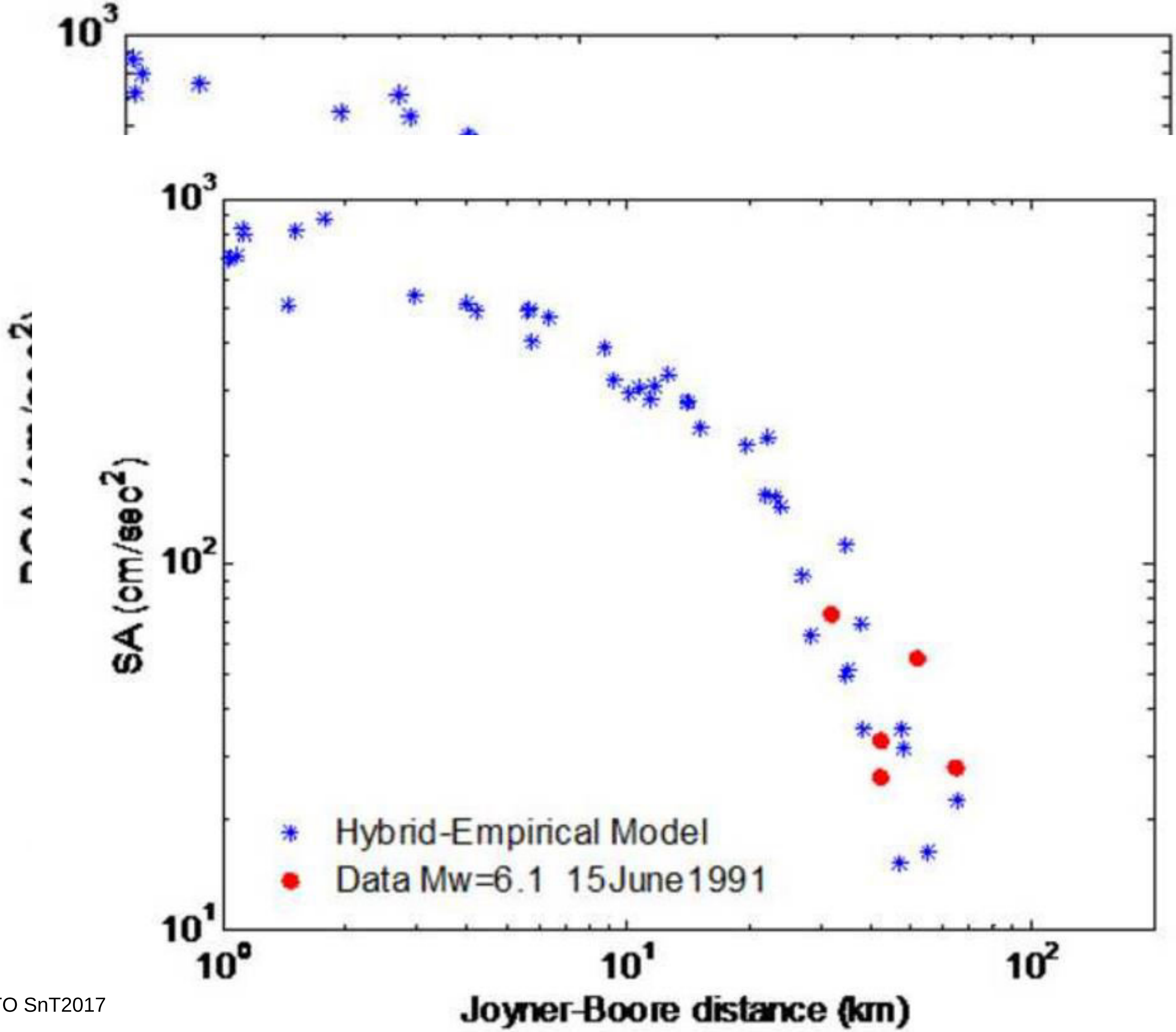
$$\mathbf{GMPE_{TARGET}(R,T) = C(R,T) \times GMPE_{HOST}}$$

# Host-to-Target (Tr-Gr, SS) (PSA-0.5 sec)

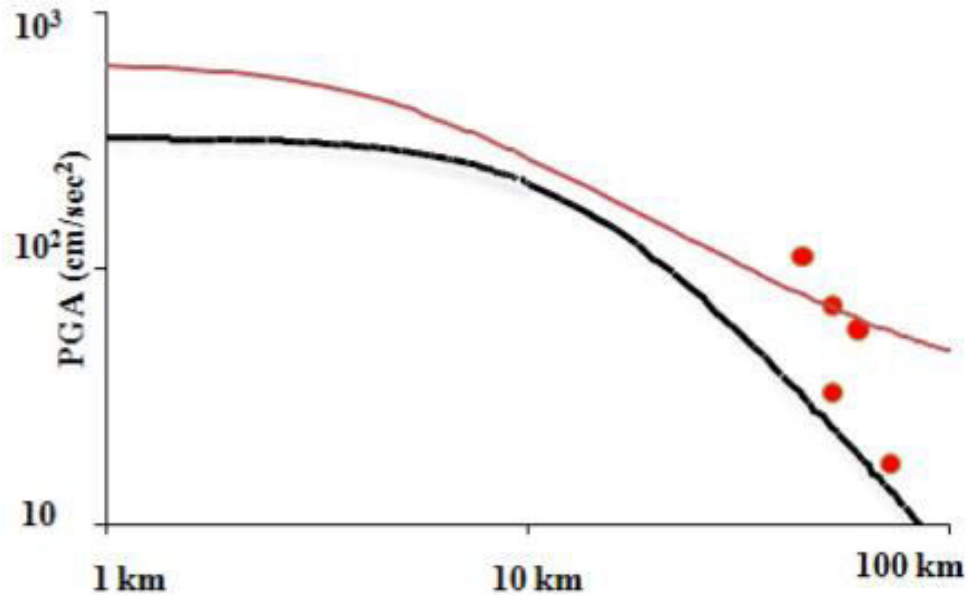


# Host-to-Target (Ir-Gr, Rev) (PSA-0.5 sec)



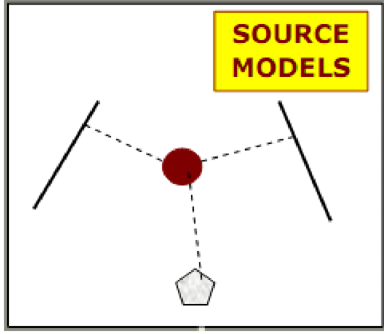


Hybrid-Empirical Model
Data Mw=6.1 15June1991
SA (cm/sec$^2$)
Joyner-Boore distance (km)
$10^3$
$10^2$
$10^1$
$10^0$
$10^1$
$10^2$



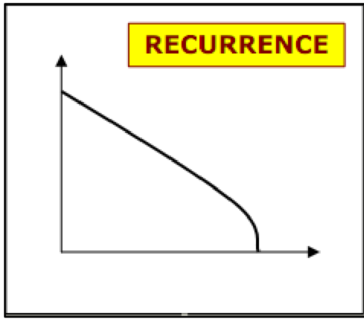

Comparison of the previous empirical GMPEs proposed for Georgia in terms of PGA against data of the 15 June 1991 earthquake ($Mw = 6.1$). Red curve is the GMPE by Smit *et al.* (2000), the black curve is the GMPE by Slejko *et al.* (2008), and the red dots are the observed data of the 15 June 1991 earthquake.

Definition of seismic sources (location of earthquake, active faults)



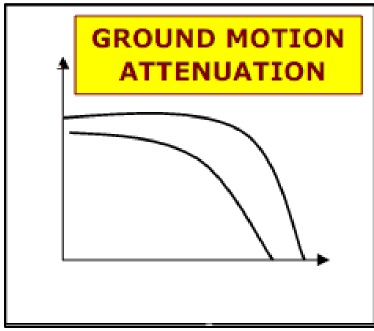

Recent developments of the Middle East catalog. **Zare, M.,Amini, H . et.al.** Journal of Seismology 2014

Estimation of seismicity parameters for each sources (Mmax, rate of occurrence)



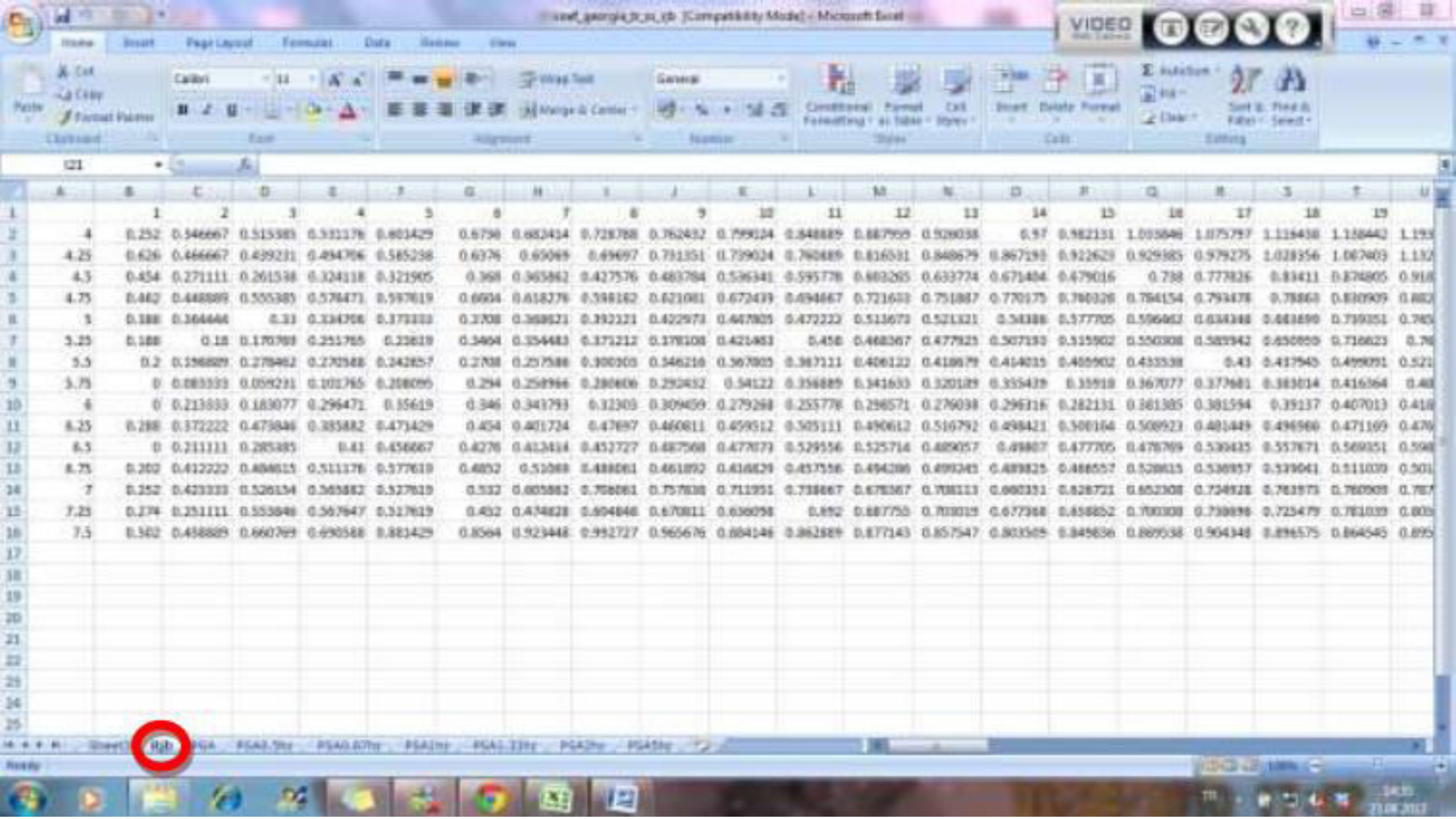

The 2014 Earthquake Model of the Middle East: seismogenic sources. **Laurentiu Danciu, Karin Şeşetyan et.al**. Bulletin of Earthquake Engineering. 2017

Ground motion estimation / selection

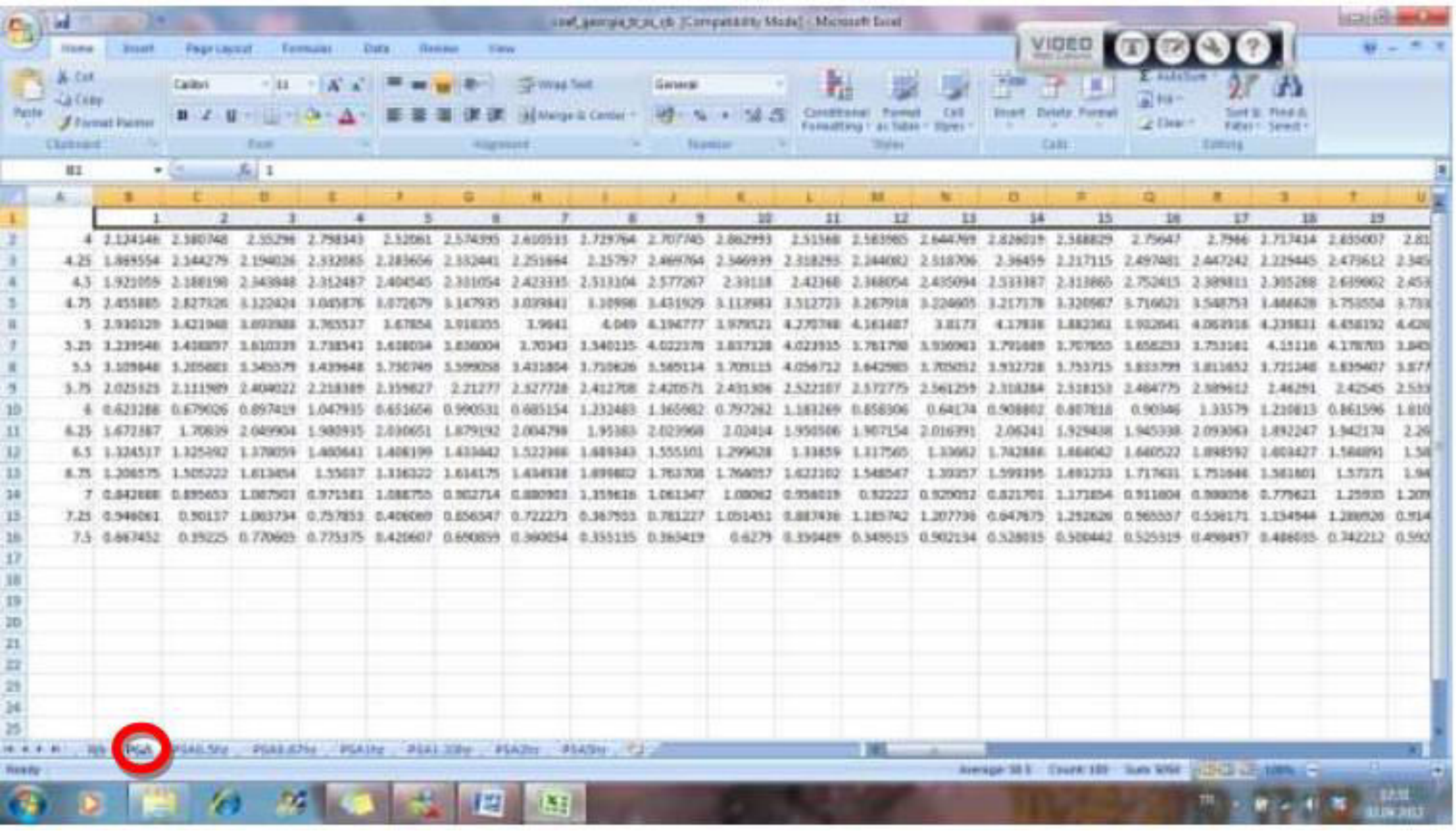



The 2014 Earthquake Model of the Middle East: ground motion model and uncertainties. Laurentiu Danciu, Özkan Kale, Sinan Akkar. Bull Earthquake Eng. 2016

**Hybrid-Empirical Ground Motion Estimations for Georgia . Tsereteli, N.,Askan, A.,Hamzehloo, H. Acta Geophysica. 2016**




**The A column shows the magnitude. The rows are up to 100 showing the Rjb values of each simulation point.**



**The numbers on this tab actually are the PGA host-to-target ratios, named as C (R), which will be multiplied with the PGA of the GMPE in the host region. The corresponding R is the distance value on first tab Rjb.**

**Similarly, the next tabs give us SA host-to-target ratios, named as C (R,T) SA**

The study of Campbell (2003) is strongly recommended before an application with the hybrid ground motion estimates calculated in our work Very quick reminder

**Ground motion amplitude(TARJET) = C (SCALING RATIO) * Ground motion amplitude (HOST)**

Assume one is to find the ground motion estimate for PGA or SA (at any period) at a certain Mw at a certain distance Rjb. We pick the corresponding coefficient from the related file. Following Campbell (2003)'s notation, we call that coefficient "F". (Please note that as we have only 1 value per parameter, for us ).

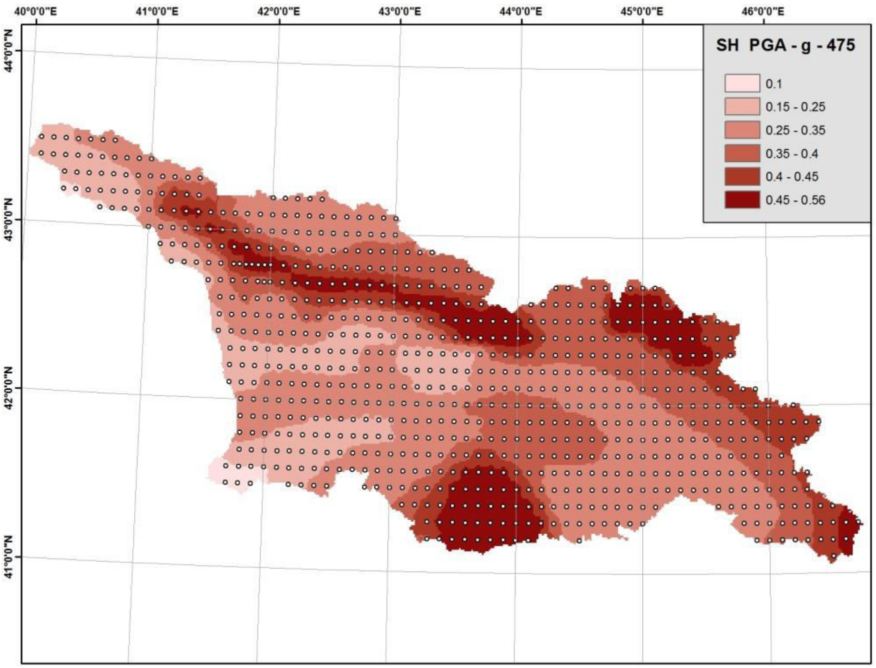
$$\ln y_i^t = \ln y_i^h + \ln \bar{F}$$

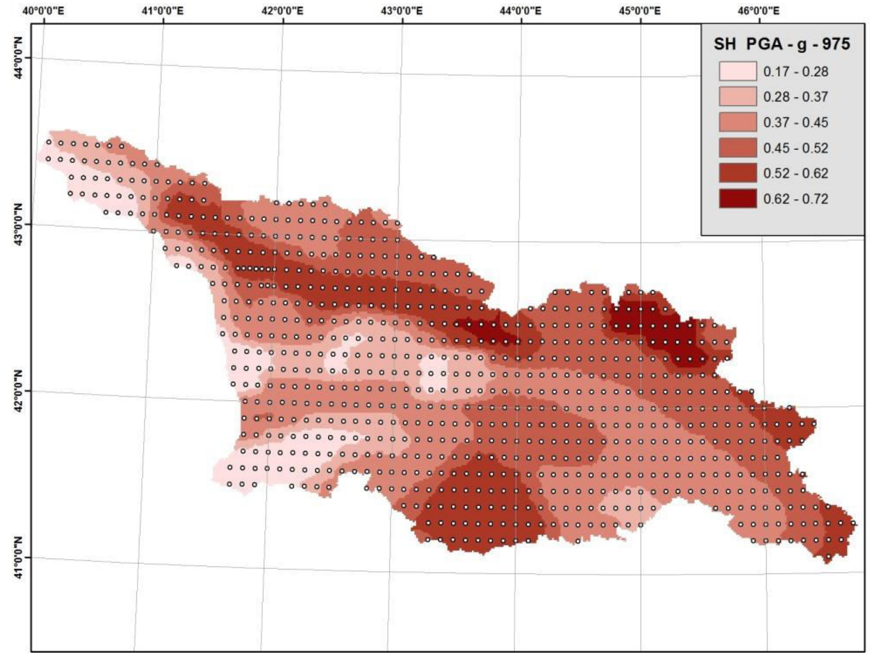
Where $y_i^h$ is the empirical ground motion estimate in host region from the I GMPE,

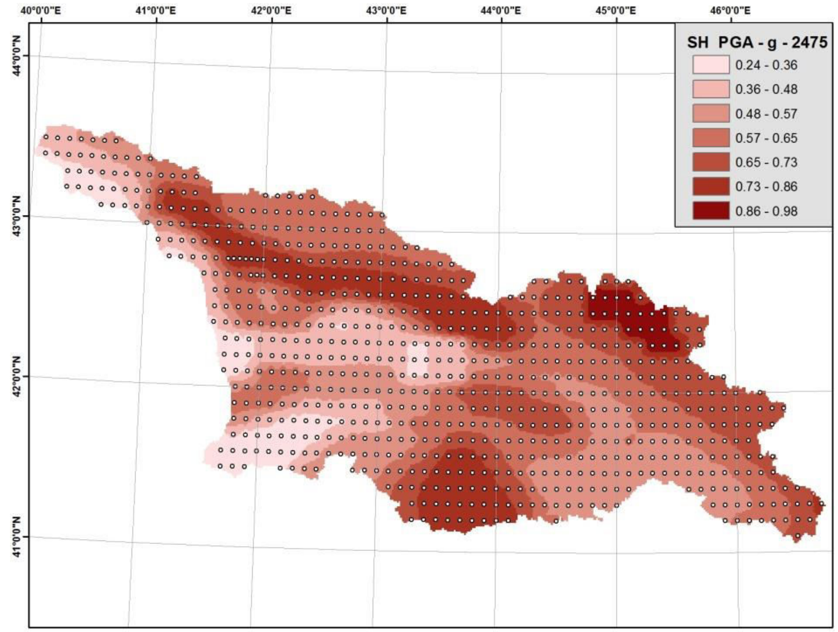
$$\ln \breve{y}^t = \sum_{i=1}^{n} w_i \ln y_i^t$$

where $\ln \breve{y}^t$ is the final hybrid ground motion estimate in the target region ( is the hybrid ground motıon estimate from the i th GMPE).

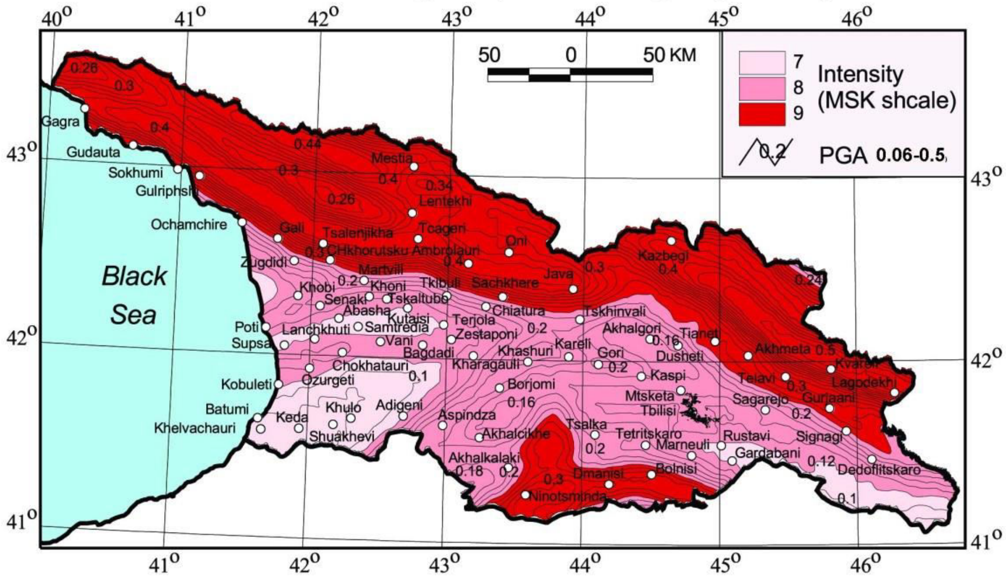
# Hazard maps  PGA

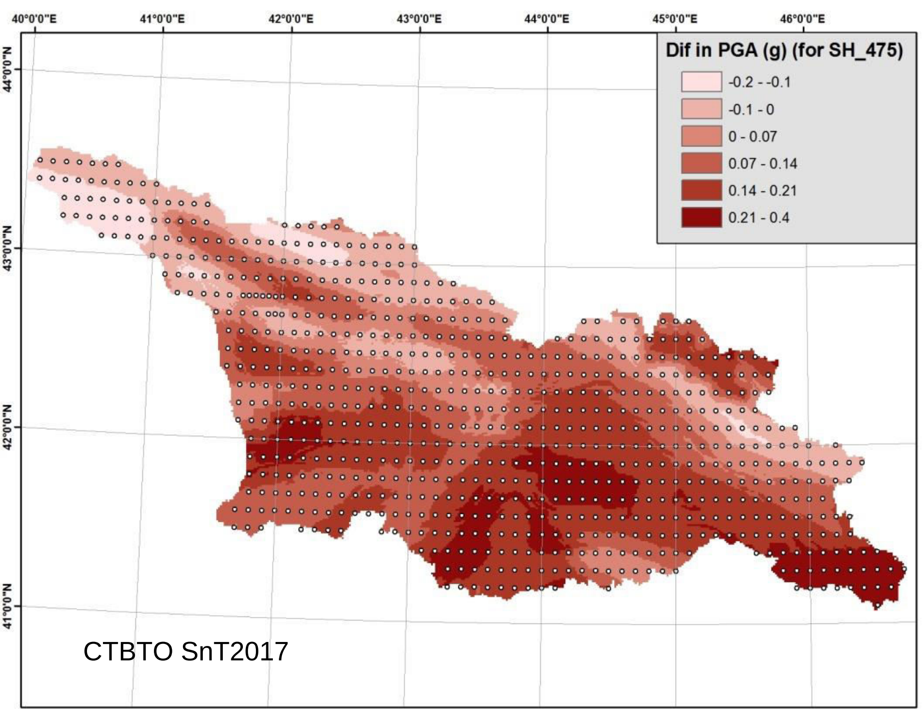


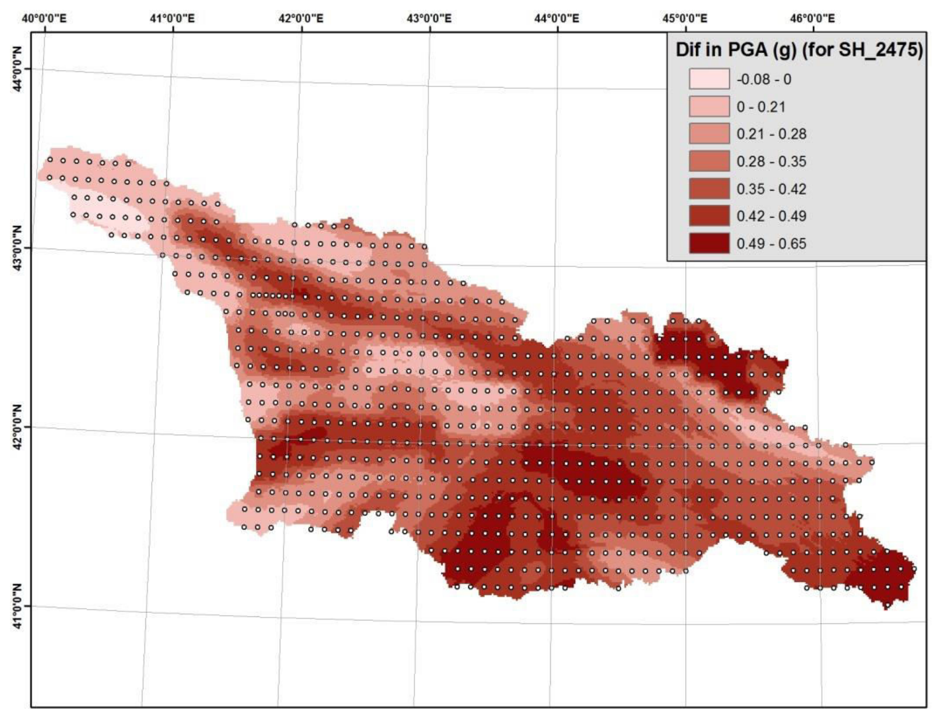



# Seismic Zoning Map of Georgia (SZ-09)



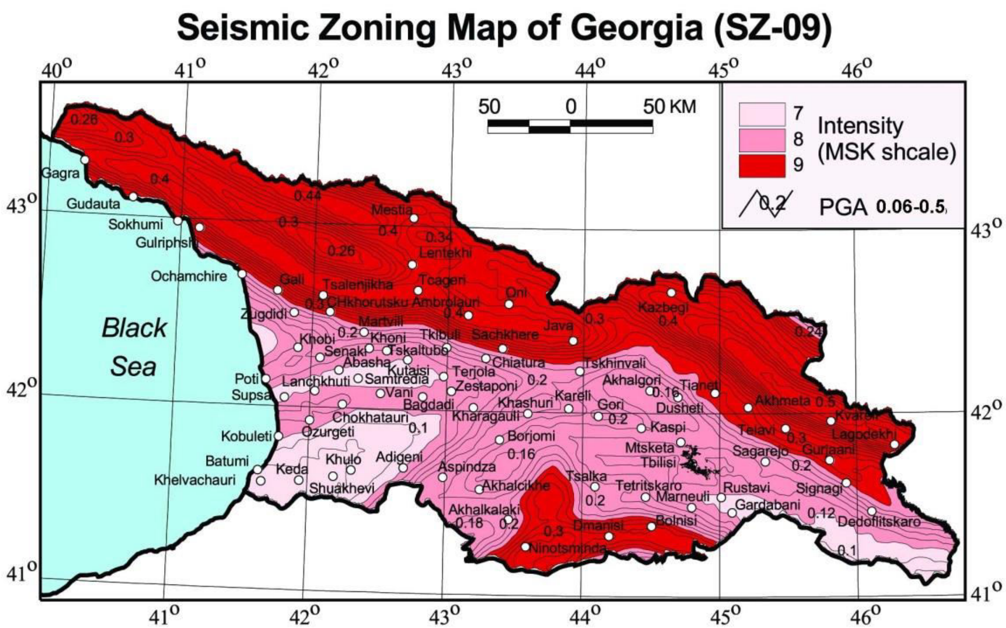
*Thank* You for Your Attention

**Probabilistic Seismic Hazard Assessment (PSHA) for the Caucasus had been undertaken in the frame of the Global Seismic Hazard Assessment Program GSHAP 1992- 1998**

**The Seismic Hazard maps were re-calculated in 2002–2007 during operation of the International Science and Technology Centre (ISTC) project: "Caucasian Seismic Information System" ISTC A651 (CauSIN)**

**Similar issues were considered in SETA project – Probabilistic Seimic Hazard Assessment for the Tbilisi test area (eastern Georgia)-**
**D. Slejko et all Bollettino di Geofisica Teorica ed Applicata 2008**

**EMME – Earthquake Model For Middle East Region 2010 -2013**




## 2475 RP

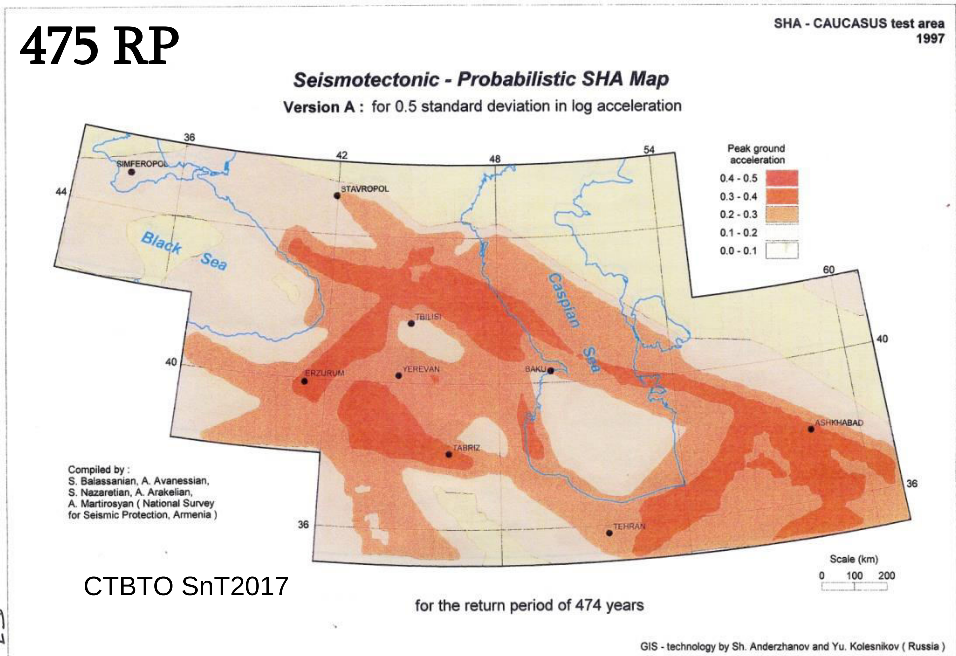
Chelidze, T., Javakhishvili, Z., Varazanashvili, O., Elashvili, M., Kolesnikov, Yu., Godoladze, T., Butikashvili, N., Ghlonti E. 2012. Seismic hazard assessment of Georgia (probabilistic approach). Institute of Geophysics, Academy of Sciences of Georgia, 15 p. http://ebookbrowse.com/seismic-hazard-assessment-of-georgia-pdf-d376754175

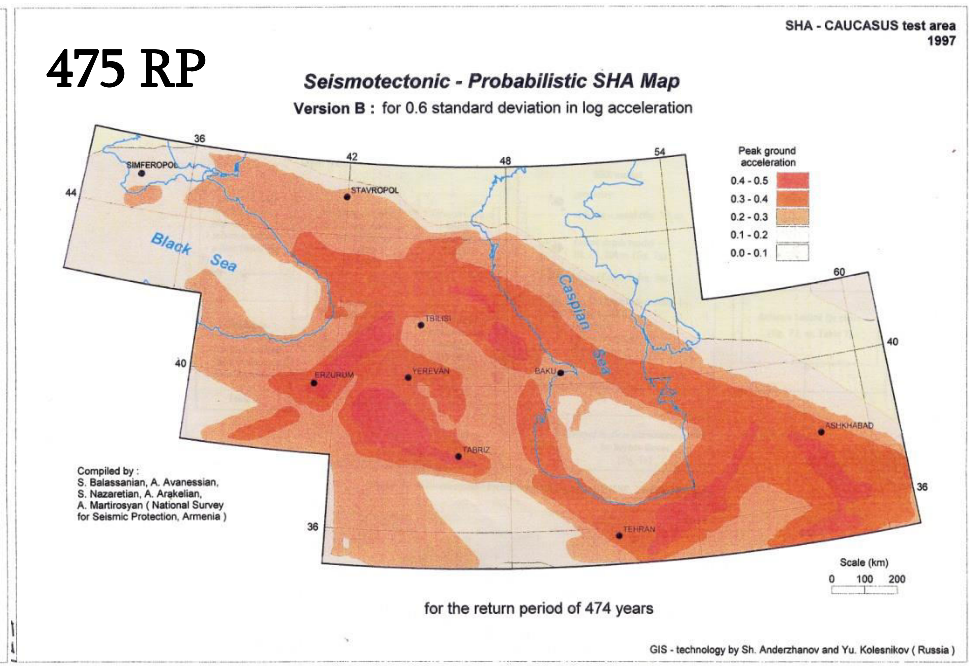
**Tbilisi**

**0.16 - 0.18 g 2% - 2475**

**0.16 - 0.2 g 10% - 475 SD=0.5**

**0.2 - 0.3 g 10% - 475 SD=0.6**



Seismic hazard assessment for the Tbilisi test area (eastern Georgia)-
D. Slejko et all [Bollettino di Geofisica Teorica ed Applicata] (impact factor: 0.38). 01/2008; 49(1):37-57.

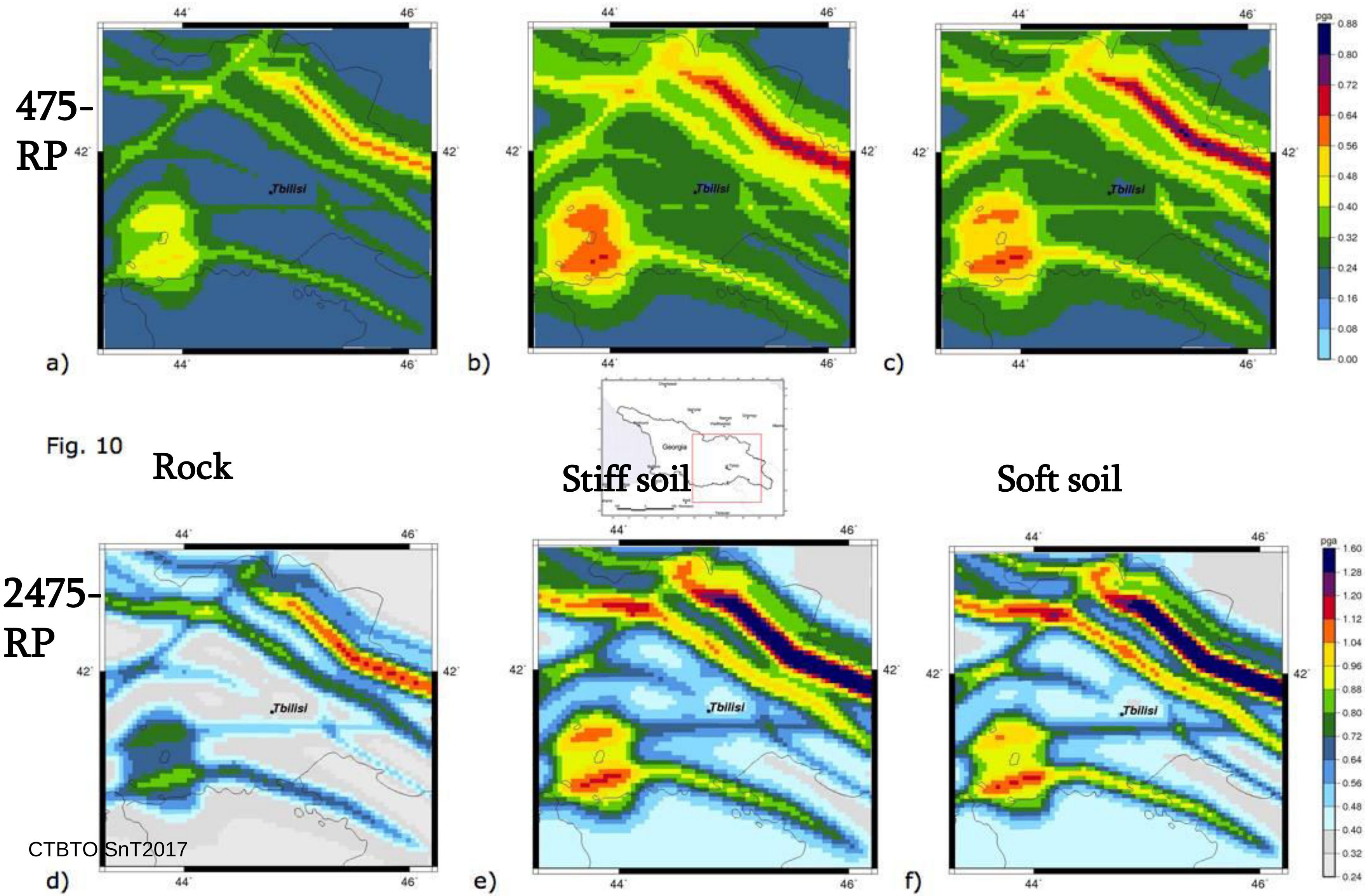
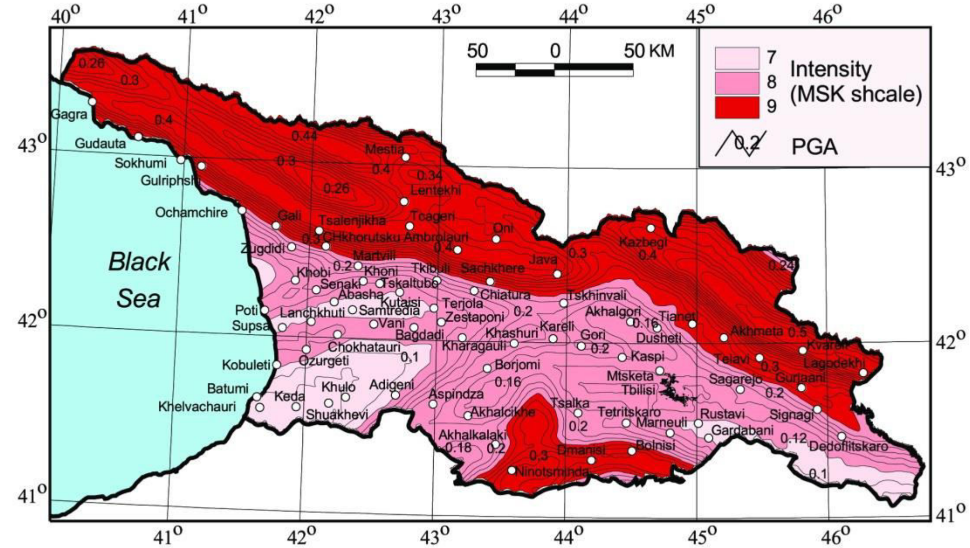
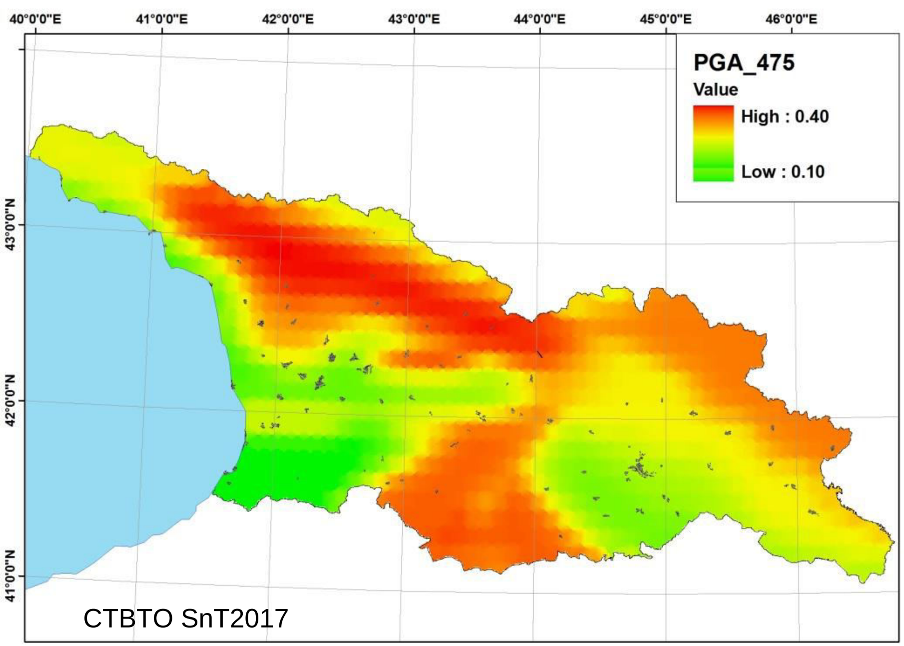
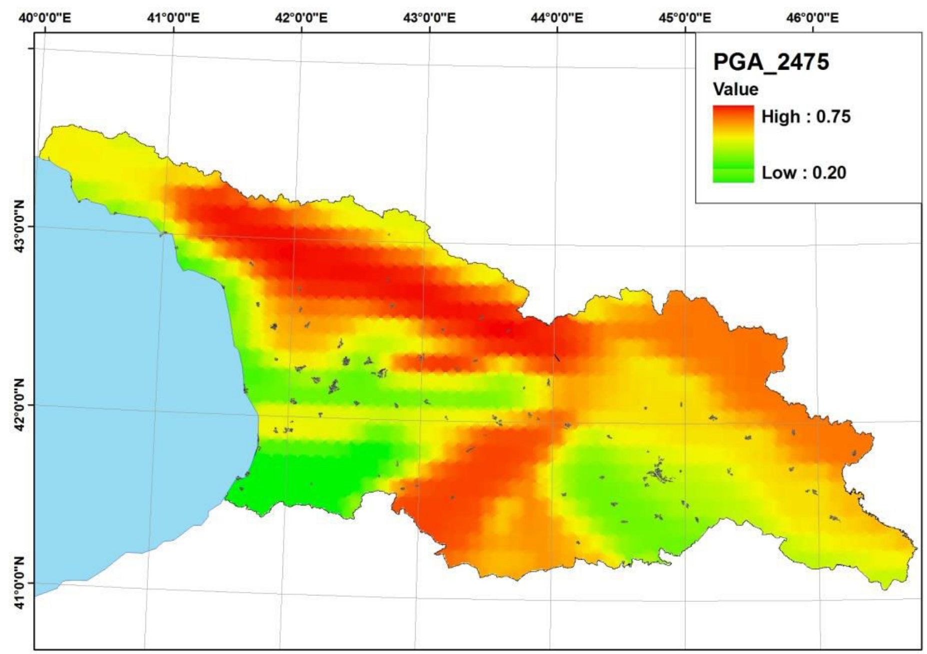



Fig. 10

## Seismic Zoning Map of Georgia (SZ-09)



# Previous Empirical Ground Motion Models in Georgia

**Smit et al. (2000)**

$$\log Y = a + b \cdot M + c \cdot \log R + d \cdot R + p \cdot \varepsilon ,$$

$$R = \sqrt{D^2 + h^2} \qquad (5)$$

| Frequency | Larger spectral horizontal ground motion on alluvium | | | | | |
|---|---|---|---|---|---|---|
| [Hz] | a | b | c | d | h | ε |
| 1.0 | -1.733 | 0.804 | -1.0 | -0.00237 | 1.0 | 0.38 |
| 1.5 | -1.673 | 0.846 | -1.0 | -0.00301 | 0.0 | 0.40 |
| 2.0 | -1.150 | 0.778 | -1.0 | -0.00273 | 6.0 | 0.40 |
| 2.5 | -0.890 | 0.768 | -1.0 | -0.00399 | 8.5 | 0.39 |
| 3.0 | -0.739 | 0.767 | -1.0 | -0.00492 | 6.5 | 0.39 |
| 4.0 | 0.052 | 0.632 | -1.0 | -0.00437 | 9.0 | 0.34 |
| 5.0 | 0.390 | 0.570 | -1.0 | -0.00341 | 6.5 | 0.31 |
| 6.0 | 0.841 | 0.472 | -1.0 | -0.00167 | 5.5 | 0.30 |
| 7.0 | 1.111 | 0.419 | -1.0 | -0.00152 | 4.5 | 0.27 |
| 8.0 | 1.433 | 0.355 | -1.0 | -0.00139 | 4.5 | 0.28 |
| 9.0 | 1.706 | 0.303 | -1.0 | -0.00117 | 5.5 | 0.28 |
| 10.0 | 1.955 | 0.254 | -1.0 | -0.00095 | 6.0 | 0.28 |
| 11.0 | 1.840 | 0.279 | -1.0 | -0.00158 | 5.0 | 0.28 |
| 12.0 | 1.834 | 0.275 | -1.0 | -0.00145 | 4.5 | 0.29 |
| 13.0 | 1.843 | 0.266 | -1.0 | -0.00109 | 4.0 | 0.29 |
| 14.0 | 1.690 | 0.298 | -1.0 | -0.00154 | 4.0 | 0.29 |
| 15.0 | 1.587 | 0.318 | -1.0 | -0.00186 | 4.0 | 0.30 |
| 16.0 | 1.591 | 0.309 | -1.0 | -0.00149 | 2.0 | 0.30 |
| 17.0 | 1.533 | 0.319 | -1.0 | -0.00151 | 0.0 | 0.30 |
| 18.0 | 1.454 | 0.332 | -1.0 | -0.00149 | 0.0 | 0.29 |
| 19.0 | 1.341 | 0.351 | -1.0 | -0.00159 | 0.0 | 0.29 |
| 20.0 | 1.301 | 0.358 | -1.0 | -0.00185 | 0.0 | 0.29 |

**(Ms) range of (1.5 – 7.1)**

**1 and 117 km**

**Caucasus, Turkey Iran**

**Kirgisia, southern Kuril Islands (Russia), Sachalin, Russia for Ms range 2- 6.8 between 4 -57 km distances.**

**Another predictive model was developed by Slejko et al (2008) within the frame of the project "Seismic Hazard Assessment for the Tbilisi Test Area"**

$$\log_{10} PGA = a + (b + cM_S)\, M_S + (d + eM_S) \log_{10} r \text{ with } r^2 = \Delta^2 + h^2$$

| T ≤ 2.0s | 2.0s < T ≤ 4.0s |
| --- | --- |
| LT#4 | LT#4 |
| ASB14 [0.35]<br>CY08 [0.35]<br>AC10 [0.20]<br>Zetal06 [0.1] | ASB14[0.45]<br>CY08 [0.45]<br>Zetal06 [0.10] |

**Akkar et al 2014**
**Chiou and Youngs (2008)**
**Akkar and Cagan (2010)**
**Cauzzi and Faccioli**
**Zhao et.al (2006)**
**Boore and Atkinson) 2008**

**Under different considerations of the EMME SM database, 6 GMPEs (ASB13, CY08, AC10, CF08, Zetal06 & BA08) perform better with respect to the other predictive models.**