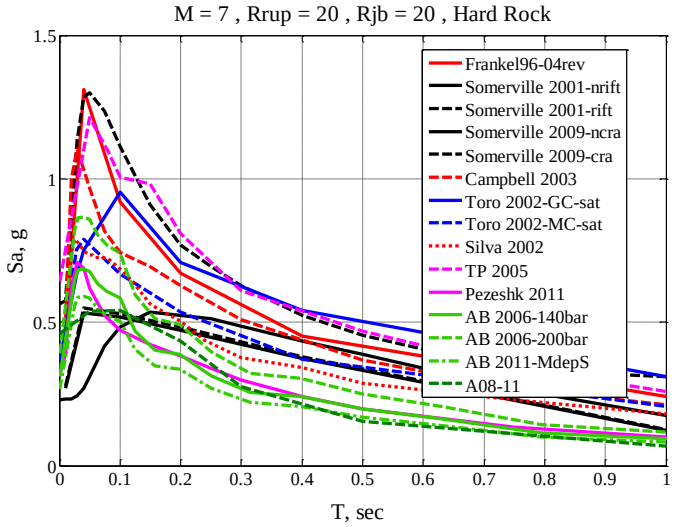
CEUS GMPEs Considered for 2014 Maps



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U.S Geological Survey, Golden, CO

USGS NSHMp Workshop on Ground Motion Prediction Equations for the 2014 Update
Wednesday, December 12, 2012
I-House, Berkeley, CA

Introduction

GMPE	Type	2008	2002
1. Frankel et al. (1996)	Single corner	Yes	Yes
2. Somerville et al. (2001)	Full waveform simulation	Yes	Yes
3. Campbell (2003)	Hybrid	Yes	Yes
4. Toro et al. (1997, 2002)	Single corner	Yes	Yes
5. Silva et al. (2002)	Single corner – const. stress drop	Yes	No
6. Tavakoli & Pezeshk (2005)	Hybrid	Yes	No
7. Atkinson & Boore (2006) • 140 stress drop • 200 stress drop	Dynamic corner	Yes	No

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• 140 stress drop			
• 200 stress drop			

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~~6. Tavakoli & Pezeshk (2005)~~	~~Hybrid~~	~~Yes~~	~~No~~
6. Pezeshk et al. (2011)	Hybrid	No	Yes
~~7. Atkinson & Boore (2006)~~ ~~• 140 stress drop~~ ~~• 200 stress drop~~	~~Dynamic corner~~	~~Yes~~	~~No~~
7. Atkinson & Boore 2006’	Dynamic corner	No	Yes
8. Atkinson 2008’	Hybrid	No	Yes

Parameters

GMPE	GS	Kappa	Distance	Site
1. Frankel et al. (1996)	r^{-1}	0.01	Rhyp, Rrup	Vs30 = 760 m/s
2. Somerville et al. (2001)			Rjb	Vs30 = 2830 m/s
3. Campbell (2003)	r^{-1}	0.01	Rrup	Vs30 = 2800 m/s
4. Toro et al. (1997, 2002)	r^{-1}	0.01	Rjb, Rrup	Vs30 = 1830 m/s
5. Silva et al. (2002)	r^{-1}	0.01	Rjb	Hard Rock
~~6. Tavakoli & Pezeshk (2005)~~	~~r^{-1}~~	~~0.01~~	~~Rrup~~	~~Hard Rock~~
6. Pezeshk et al. (2011)	$r^{-1.3}$	0.02	Rrup	Class A, Vs30 >= 2000 m/s
~~7. Atkinson & Boore (2006)~~ ~~• 140 stress drop~~ ~~• 200 stress drop~~	~~$r^{-1.3}$~~	~~0.02~~	~~Rrup~~	~~Vs30 a parameter~~
7. Atkinson & Boore 2006'	$r^{-1.3}$	0.02	Rrup	Vs30 a parameter
8. Atkinson 2008'	$r^{-1.3}$	0.02	Rjb	Vs30 a parameter

Reference Site Condition

- USGS Maps are generated for firm rock conditions, NEHRP BC class (Vs30 = 760 m/s)
  Vs30 = 760 m/s in the CEUS is quite different from the WUS, especially confusing in the Gulf Coast (poorly defined)

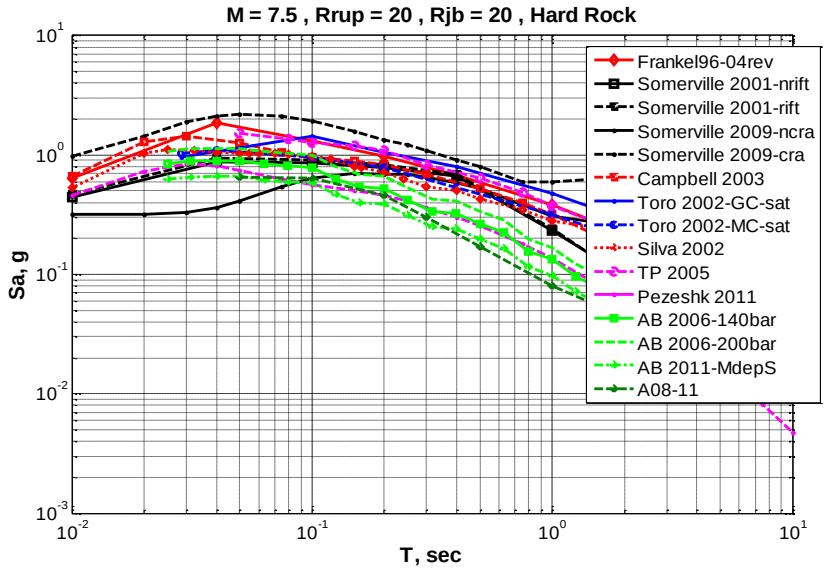
- Frequency dependent factors are used to convert ground motions predicted for hard rock to firm rock

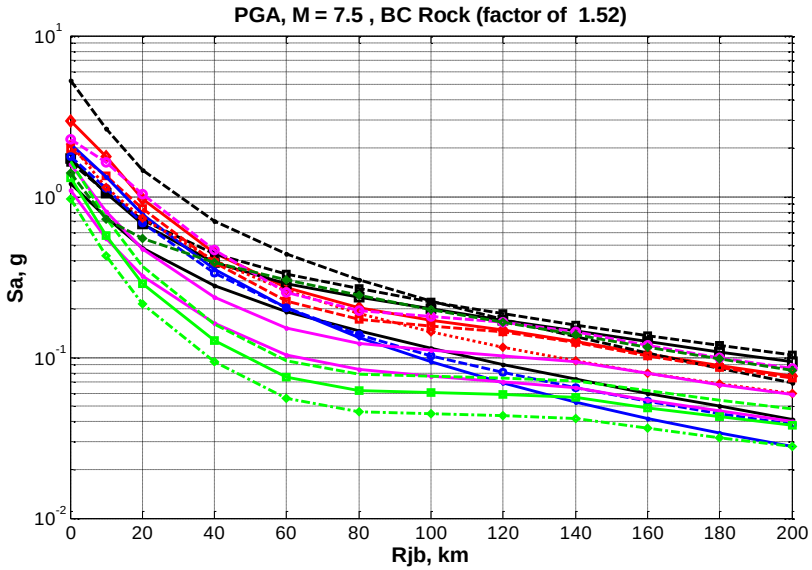
2008 USGS OFR (Frankel 1996):
1.52 for PGA
1.74 for 0.1s
1.76 for 0.2s
1.72 for 0.3s
1.58 for 0.5s
1.34 for 1.0s
1.20 for 2.0s

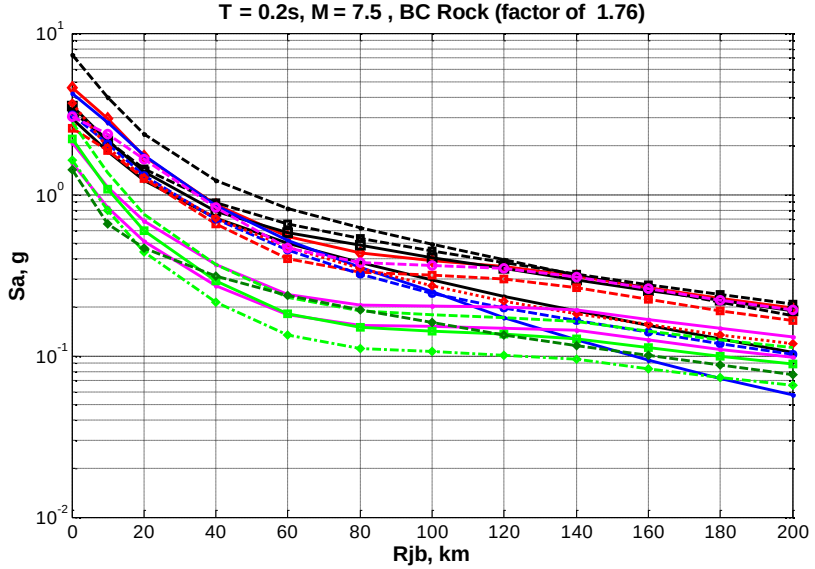
Atkinson and Boore (2011, Table 2):
1.04 for PGA
1.04 for 0.1s
1.31 for 0.2s
1.41 for 0.32s
1.40 for 0.5s
1.27 for 1.0s
1.26 for 2.0s

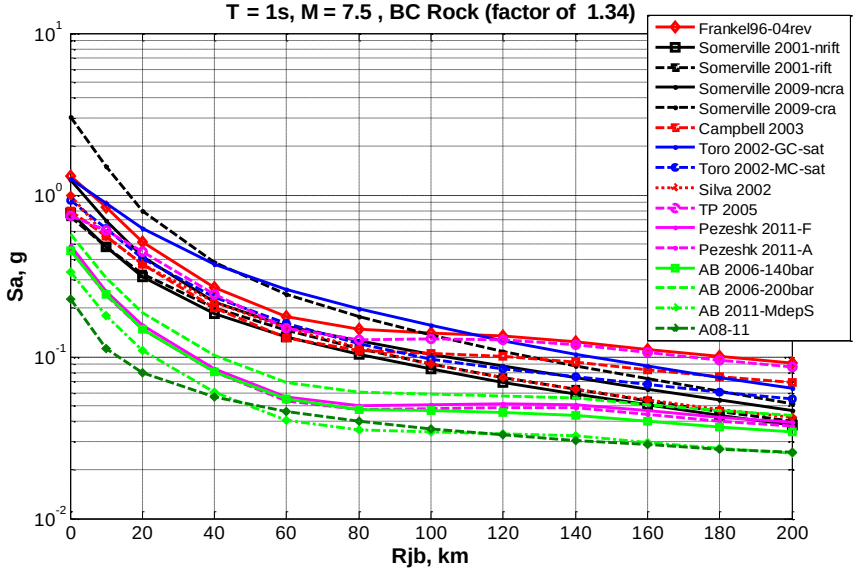
- In this presentation, the scaling factors are applied to all models except Atkinson & Boore (2006, 2011) and Atkinson 2008'. There is a question about whether or not we should apply a range of kappa (amplification factors) to each of the GMPEs.

All GMPEs: M=7.5









Frankel et al. (1996):

Constructed especially for 1996 maps.
Single corner frequency, point source stochastic model.
Geometric Spreading: r^{-1} (10 to 70 km), r^{0} (70 to 130 km), $r^{-0.5}$ (>130km)
κ = 0.01

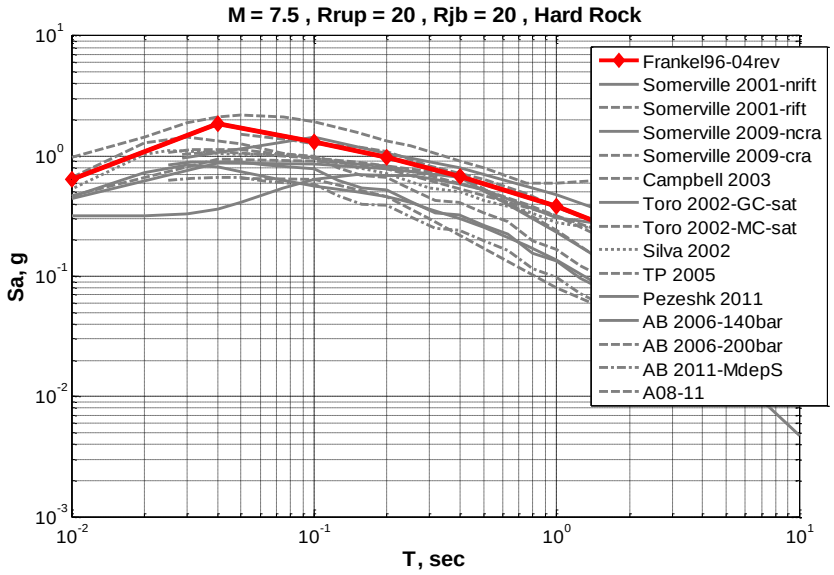
- **Input Parameters:**
  M_w, R_{hyp}, T
- **Site Conditions:**
  Firm rock (Vs30 = 760 m/s)
  frequency dependent amplification factors given for firm rock
- **Directionality:**
  --

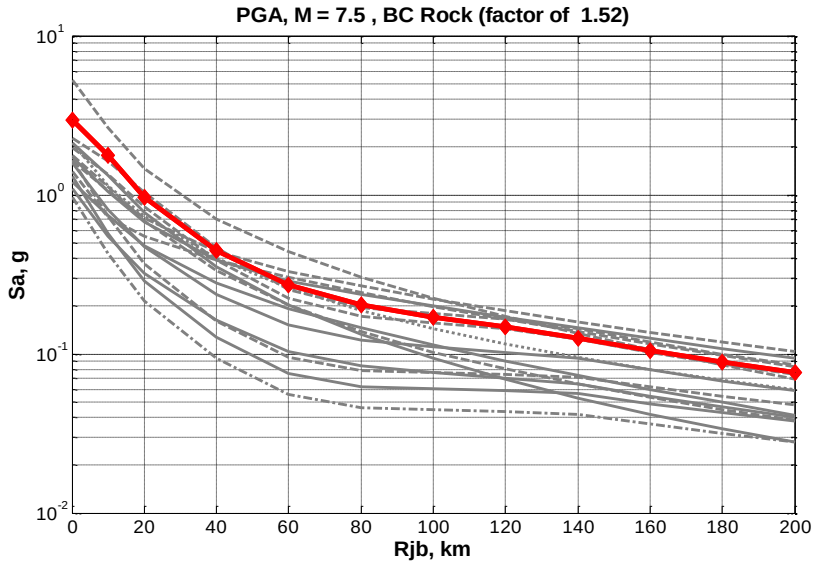
- **Applicability:**
  CEUS
  M_w = 4.4 -- 8.2
  R_{hyp} = 10 – 1000 km
  T = PGA, 0.2, 0.3, 1.0 s

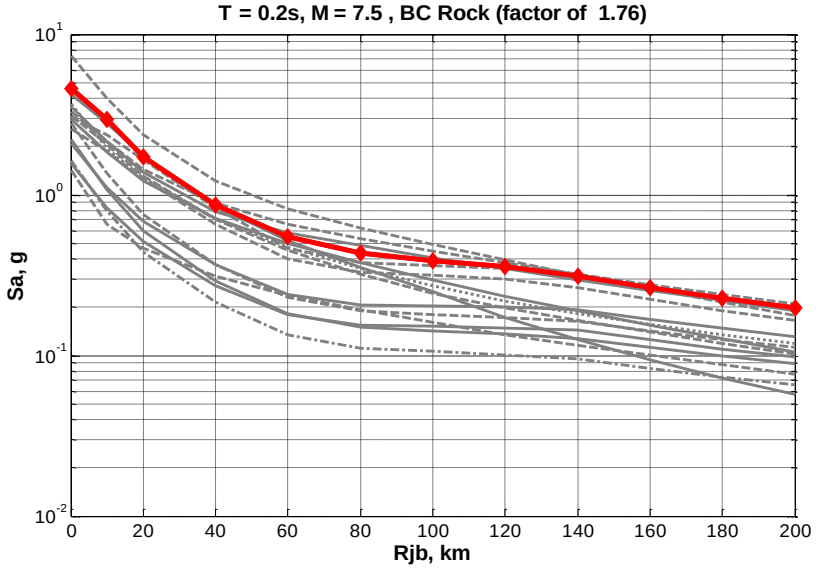
Reference:

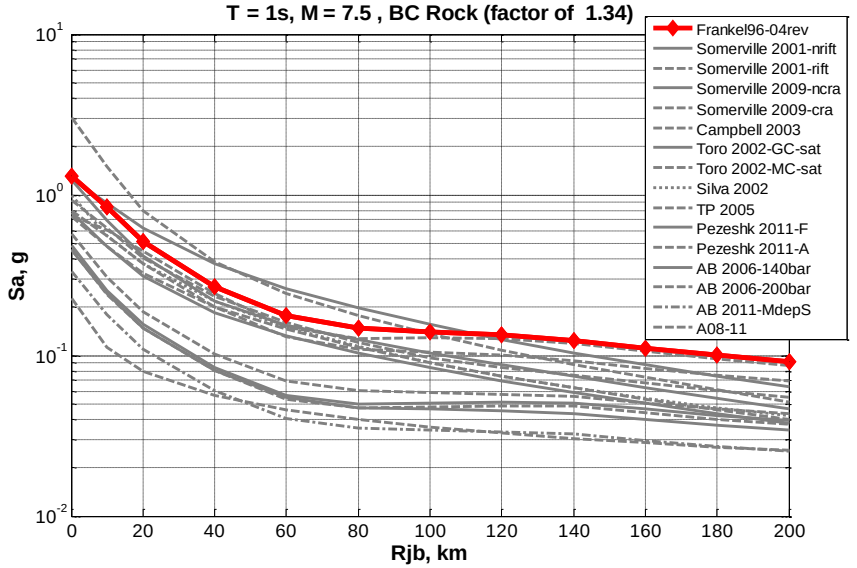
- Frankel, A., Mueller, C., Barnhard, T., Perkins, D., Leyendecker, E.V., Dickman, N., Hanson, S., Hopper, M. (1996). National Seismic-Hazard Maps: Documentation June 1996, *Open-File Report 96-532*. U.S. Department of the Interior, U.S. Geological Survey. **Appendix A, Tables A1-A4**
- Parameterized by EPRI 2004, hard rock (used to plot, Rjb adjustment)

Frankel et al. (1996): M=7.5









Somerville et al. (2001):

Full waveform Simulations.
Geometric Spreading: r^{-1}
κ = 0.006

- **Input Parameters:**
  M_w, R_{jb}, T

  Depth distribution:
  - rifted (deeper) domains
  - non-rifted (shallow) domains

- **Site Conditions:**
  Hard rock (Vs30 = 2830 m/s)

- **Directionality:**
  --

- **Applicability:**
  CENA
  Horizontal & Vertical comps
  M_w= 6.0 - 7.5
  R_{jb}= 0 – 500 km
  T = 0 – 4 s
  Mechanism siml: reverse

Reference:

- Somerville, P., Collins, N., Abrahamson, N., Graves, R., and Saikia, C., 2001, Ground motion attenuation relations for the Central and Eastern United States– Final report, June 30, 2001: Report to U.S. Geological Survey for award 99HQGR0098, 38 p.

Somerville et al. (2009):

Use source scaling relations from Somerville et al. (2001), but use regional rupture models and crustal velocity models in Australia.
Geometric Spreading: r^{-1}
κ = 0.006 (cratonic) and 0.04 (non-cratonic)

❑ Input Parameters:

M_w, R_{jb}, T

Region:
- cratonic
- non-cratonic

❑ Site Conditions:

Rock (Vs30 = 865 m/s)

❑ Directionality:

--

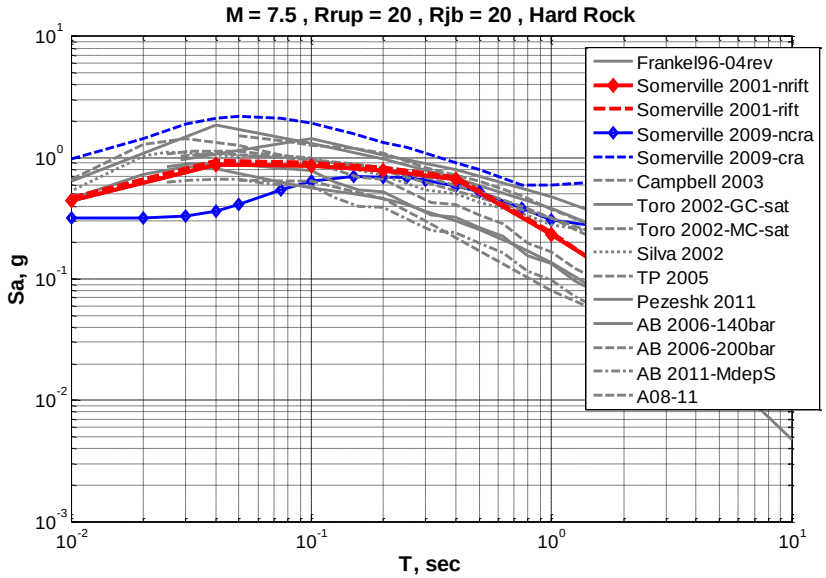
❑ Applicability:

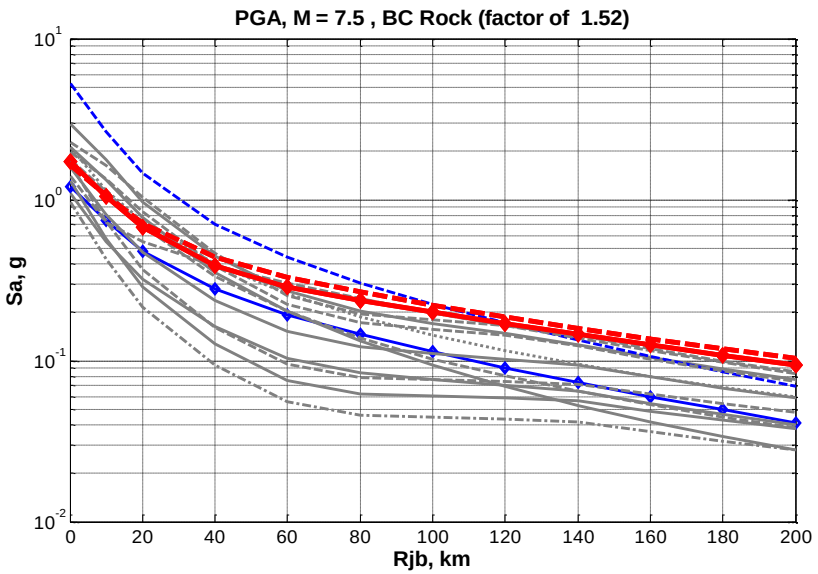
Australia
M_w= 5.0 - 7.5
R_{jb}= 0 – 500 km
T = PGA, PGV, 0.01 – 10 s

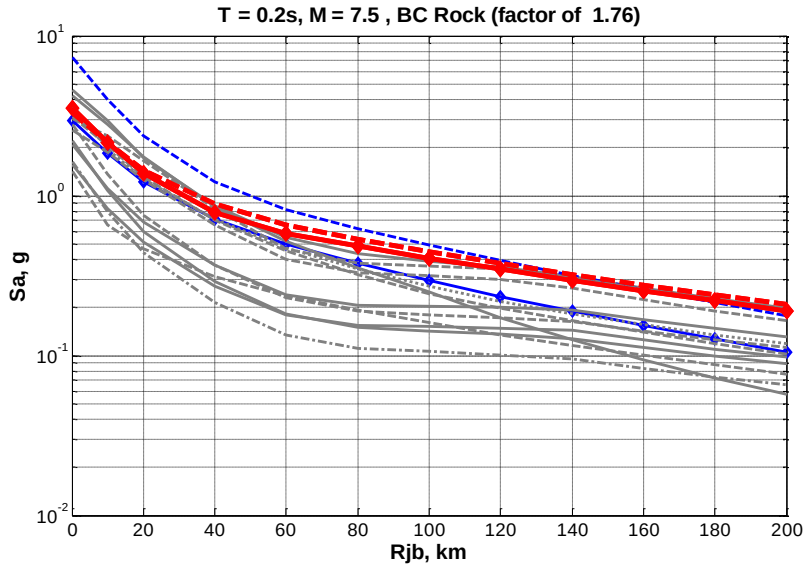
Reference:

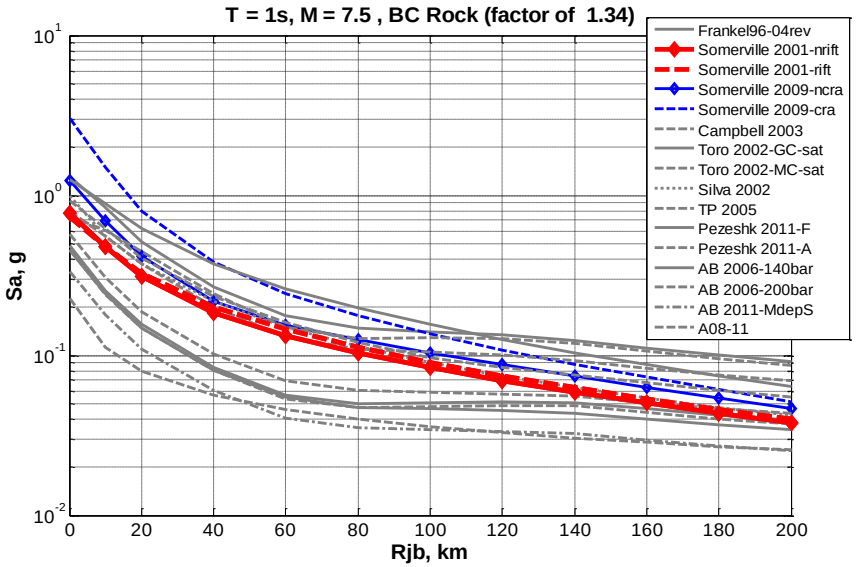
- Somerville, P., Graves, R., Collins, N., Song, S.G., Ni, S., Cummins, P. (2009). Source and ground motion models of Australian earthquakes, *Proceedings of the 2009 Annual Conference of the Australian Earthquake Engineering Society*.

Somerville et al. (2001, 2009): M=7.5









Campbell (2003):

Hybrid empirical model. Uses simulations in SCRs to adjust GMPEs in WUS.

Simulations: single corner model

Empirical GMs: Abrahamson-Silva 1997, Campbell 1997, Sadigh 1997, Campbell-Bozorgnia 2003.

Stress drop ratio (E/W): 1.5 (150 vs 100 bar)
κ ratio (E/W) = 0.15 (0.006 vs 0.04)

❑ **Input Parameters:**
M_w, R_{rup}, T

❑ **Site Conditions:**
Hard rock (Vs30 = 2800 m/s)

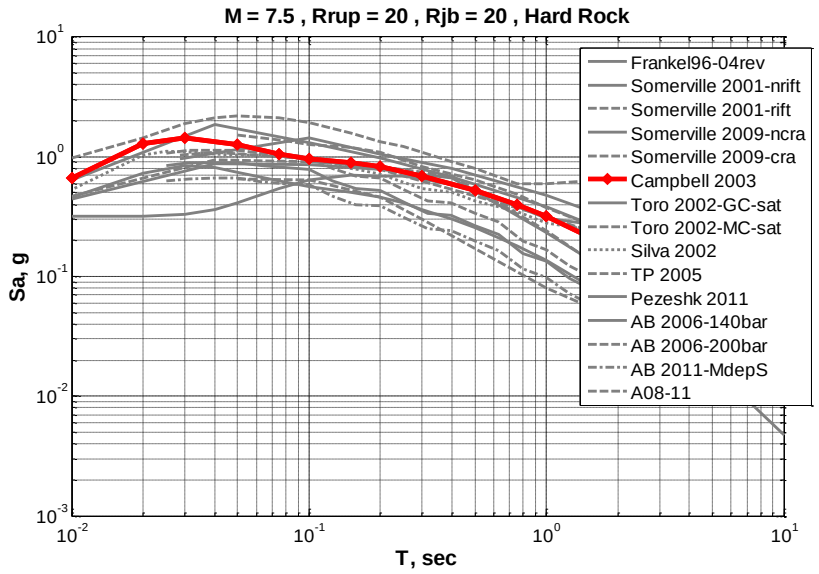
❑ **Directionality:**
Geometric mean

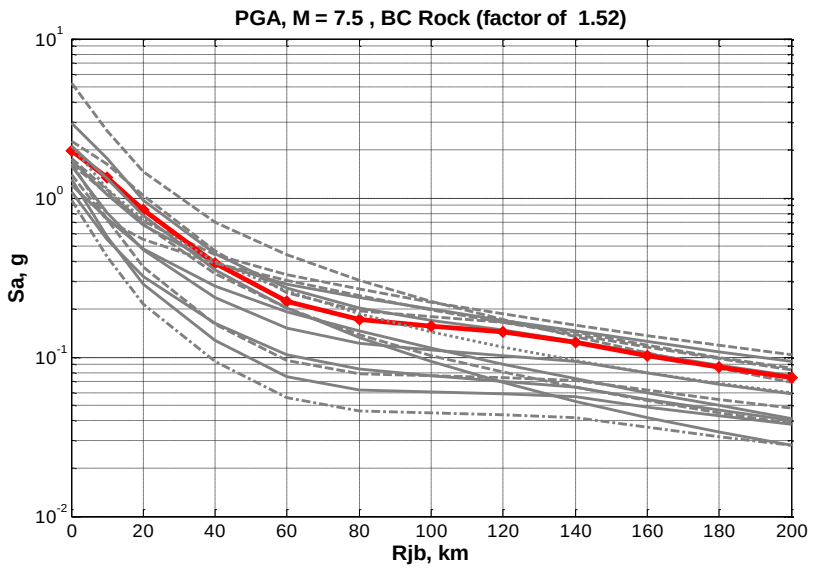
❑ **Applicability:**
ENA
M_w = 5.0 – 8.2
R_{rup} = 0 – 1000 km
T = 0.01 – 4 s

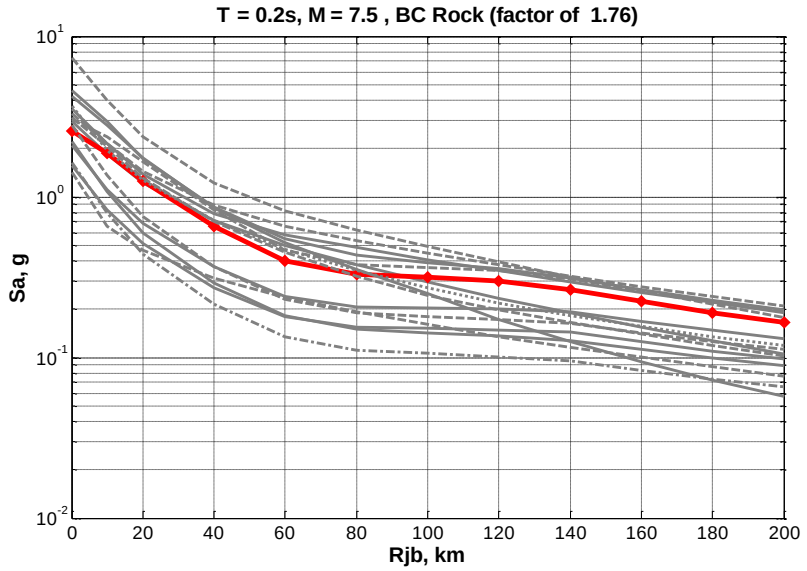
Reference:

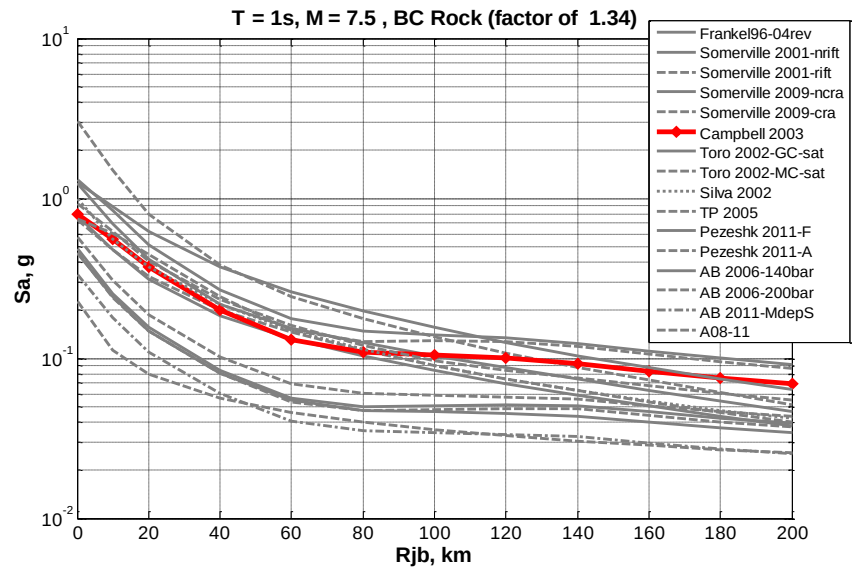
- Campbell, K. W. (2003). Prediction of strong ground motion using the hybrid empirical method and its use in the development of ground motion (attenuation) relations in eastern North America. *Bulletin of the Seismological Society of America*, **93**, 1012–1033.

Campbell (2003): M=7.5









Toro et al. (1997) -- Toro (2002):

Single corner point source model. Modified by Toro (2002) to account for extended source effects (i.e., magnitude saturation).

Geometric Spreading: r^{-1}
κ = 0.006

❑ Input Parameters:

M_w, R_{jb}, R_{rup}, T

Crustal Region:
- Midcontinent (MC)
- Gulf Coast (GC)

❑ Site Conditions:

Hard rock (Vs30 = 6000 ft/s)

❑ Directionality:

--

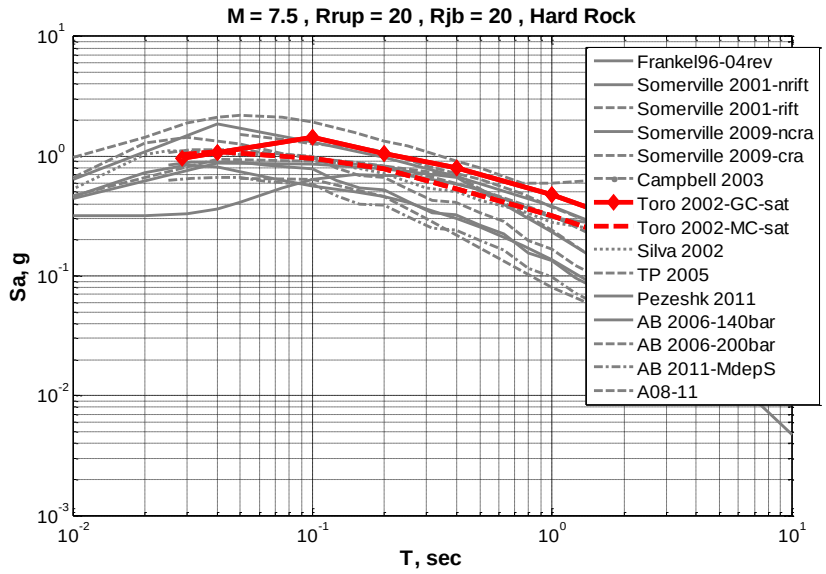
❑ Applicability:

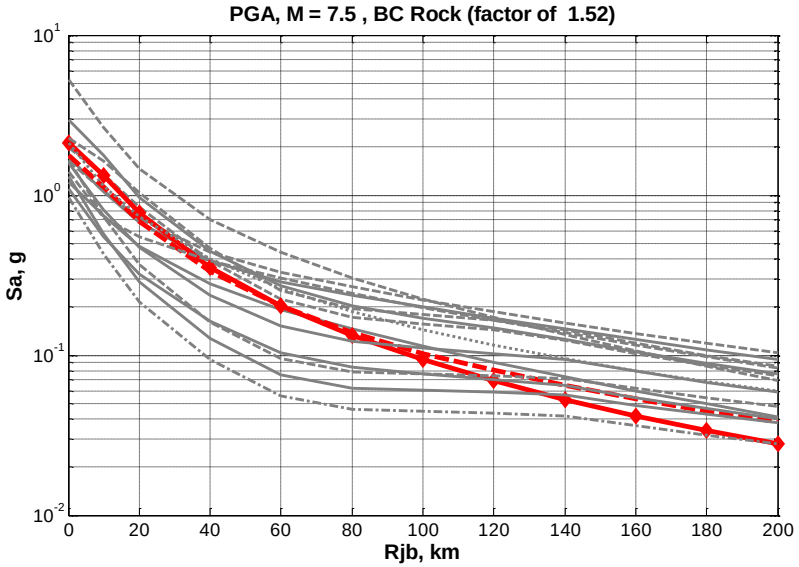
CENA
M_w= 5 – 8
R_{jb}= 1 – 500 km
T = PGA, 0.03 – 2 s

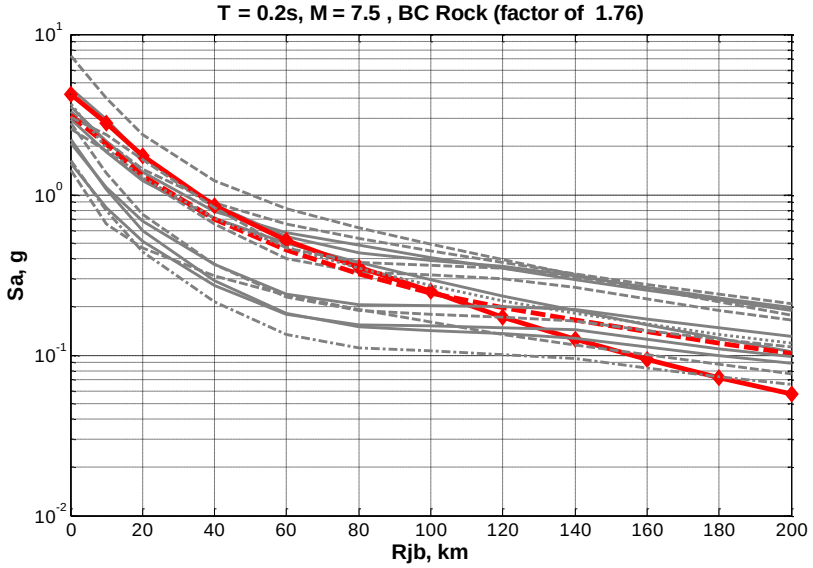
Reference:

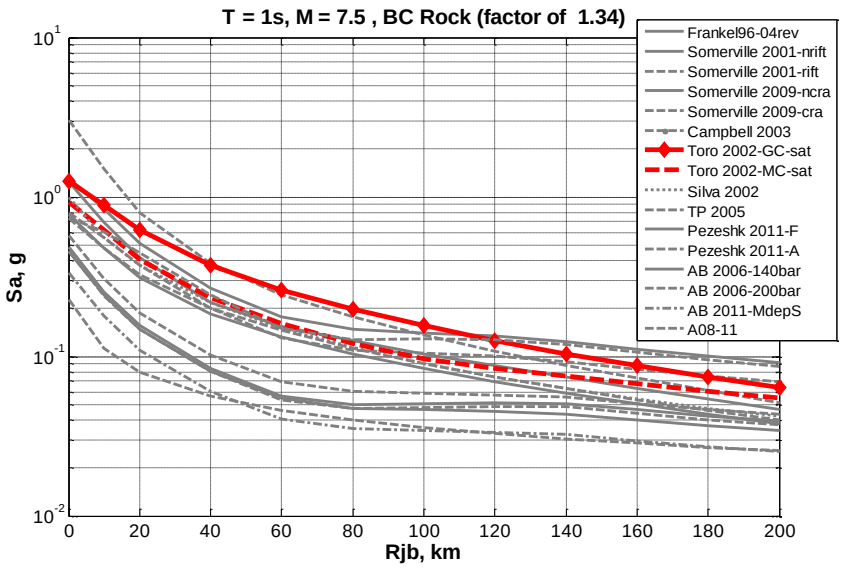
- Toro, G.R. (2002). Modification of the Toro et al. (1997) attenuation equations for large magnitudes and short distances, *Technical Report, Risk Engineering*.
- Toro, G.R., Abrahamson, N.A., Schneider, J.F. (1997). Model of strong ground motions from earthquake in central and eastern North America: Best estimates and uncertainties, *Seismological Research Letters*, **68:1**, 41–57.

Toro (2002): M=7.5









Silva et al. (2002):

Single corner model w/ constant stress drop and magnitude saturation.

Geometric Spreading: r^{-1}

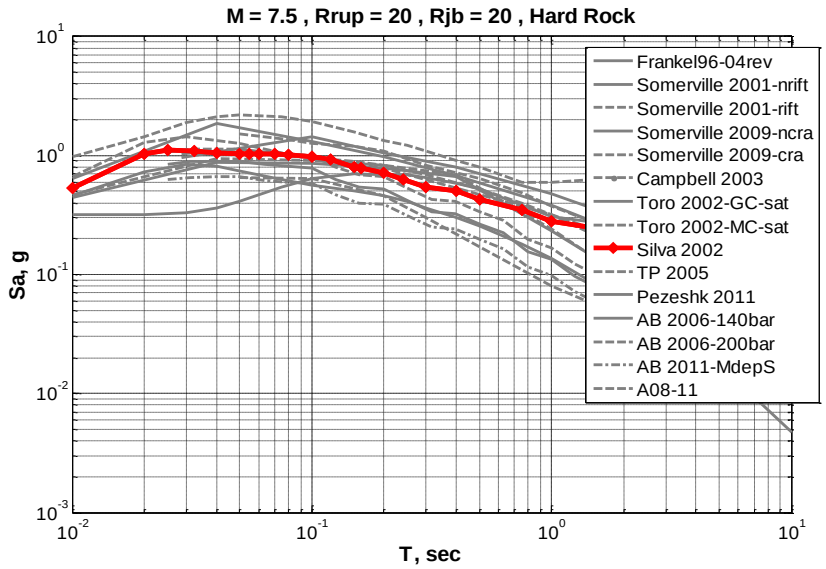
κ = 0.006

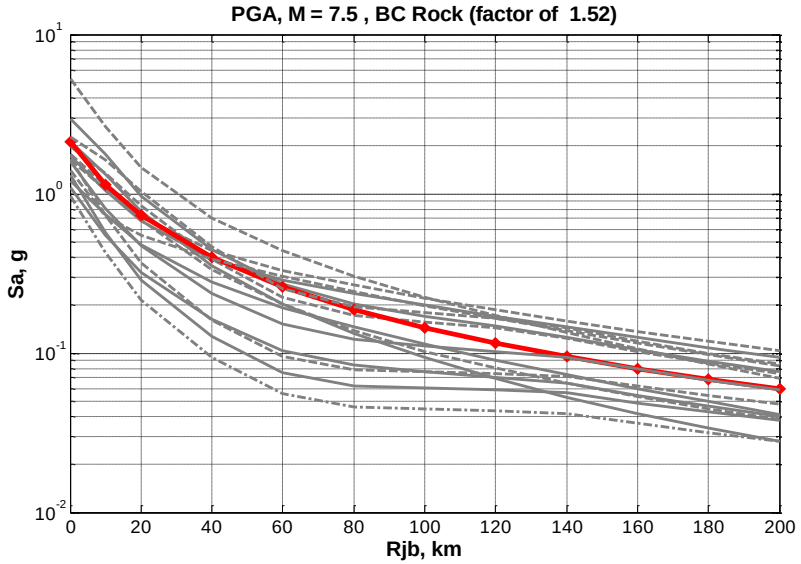
- **Input Parameters:**
  M_w, R_{rup}, T
- **Site Conditions:**
  Hard rock
- **Directionality:**
  Average horizontal component
- **Applicability:**
  CENA
  M_w= 4.5 – 8.5 (simulations)
  R_{jb}= 1 – 400 km (simulations)
  T = PGA, PGV, 0.01 – 10 s

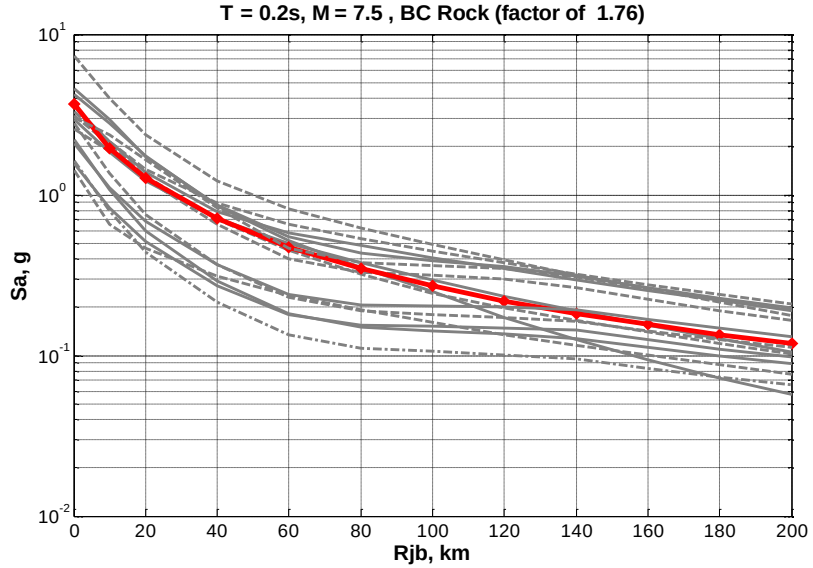
Reference:

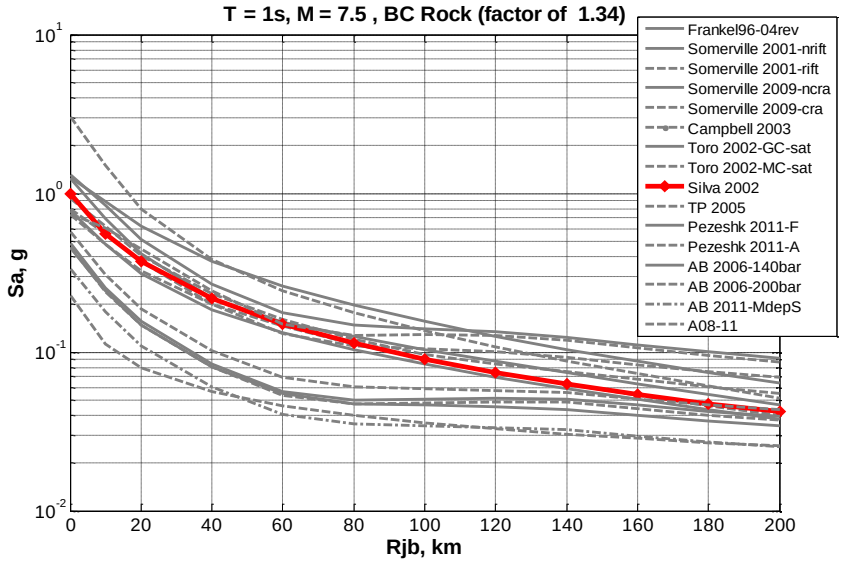
- Silva, W., Gregor, N., Darragh, R. 2002 (Nov). Development of regional hard rock attenuation relations for central and eastern North America. *Tech. rept. Pacific Engineering and Analysis*.

Silva (2002): M=7.5









Tavakoli & Pezeshk (2005):

Hybrid empirical model .

Stochastic Simulations: double corner, Geometric Spreading (r^{-1})

ENA: κ = 0.006

WNA: κ = 0.04

Empirical GMs: Abrahamson-Silva 1997, Campbell 1997, Sadigh et al. 1997

- **Input Parameters:**
  M_w, R_{rup}, T
- **Site Conditions:**
  Hard rock (Vs30 = 2768-3600m/s)
- **Directionality:**
  Average horizontal component
- **Applicability:**
  ENA
  M_w= 5.0 – 8.2
  R_{rup}= 0 – 1000 km
  T = 0.00 – 4 s

Reference:

- Tavakoli B., and, Pezeshk, S (2005). Empirical-stochastic ground-motion prediction for Eastern North America, *Bulletin of the Seismological Society of America,* Vol. 95, pp. 2283-2296, doi: 10.1785/0120050030.

Pezeshk et al. (2011):

Hybrid empirical model .

Stochastic Simulations: Single corner model, Geometric Spreading ($r^{-1.3}$)

ENA: κ = 0.005 , stress-drop = 250

WNA: κ = 0.04 , stress-drop = 80

Empirical GMs: 5 NGA GMPEs

❑ **Input Parameters:**

M_w, R_{rup}, T

❑ **Site Conditions:**

Hard rock (Vs30 = 2768-3600m/s)

❑ **Directionality:**

GMRotI50

❑ **Applicability:**

ENA

M_w= 5.0 – 8.2

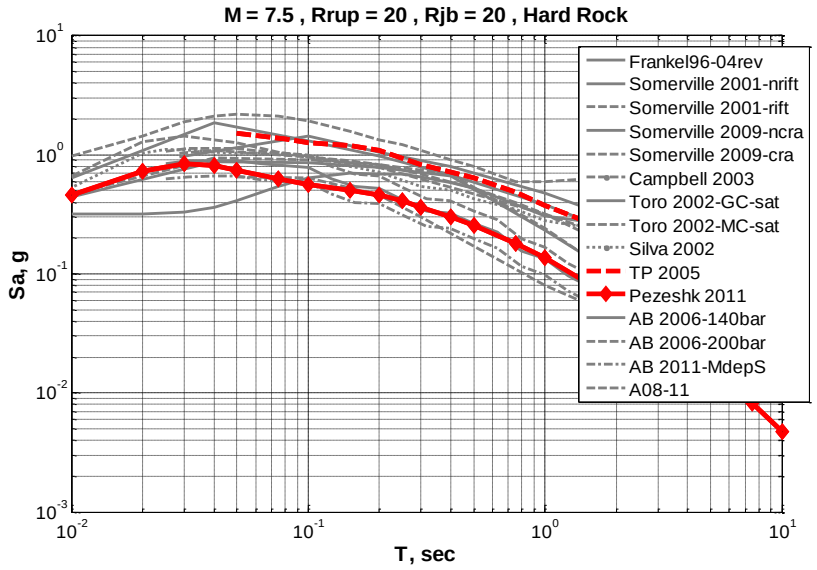
R_{rup}= 0 – 1000 km

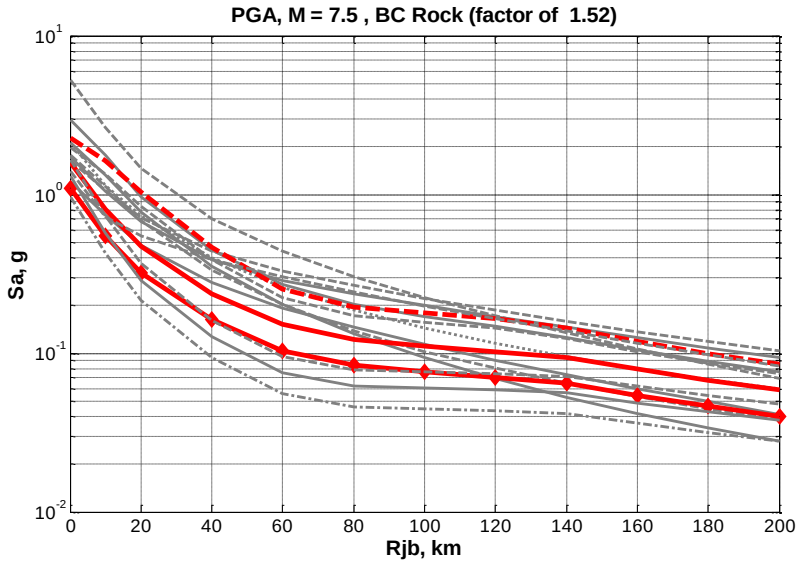
T = 0.00 – 4 s

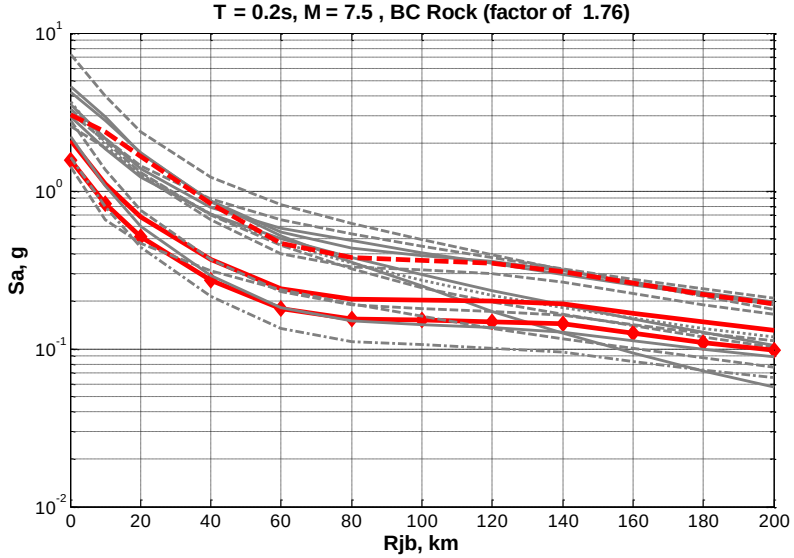
Reference:

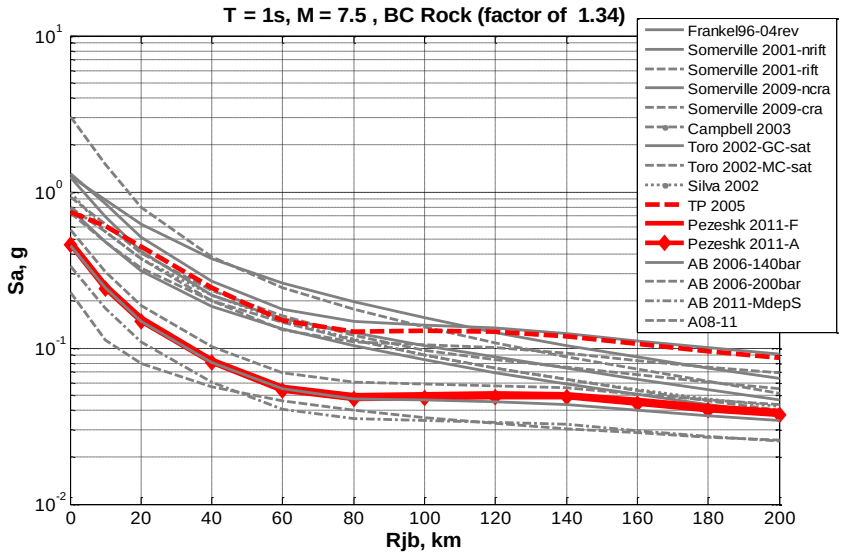
- Pezeshk, S., Zandieh, A., Tavakoli, B. (2011). Hybrid Empirical Ground-Motion Prediction Equations for Eastern North America Using NGA Models and Updated Seismological Parameters, *Bulletin of the Seismological Society of America*, **101:4**, 1859-1870, August 2011, doi: 10.1785/0120100144

Pezeshk (2005, 2011): M=7.5









Atkinson & Boore (2006):

Dynamic corner frequency source model.

Geometric Spreading: faster near-source attenuation ($r^{-1.3}$ vs r^{-1})
κ = 0.005 (sensitivity done for 0.002-0.008)

❑ **Input Parameters:**

M_w, R_{rup}, T, Site
Stress-drop (default 140)

❑ **Site Conditions:**

Hard rock (Vs30 >= 2000 m/s)
Soil sites (Vs30 = 760 m/s)
Amplification factors give for other soil sites

❑ **Directionality:**

--

❑ **Applicability:**

ENA
M_w= 4 – 8 (simulations)
R_{rup}= --
T = PGA, PGV, 0.03 – 5 s

Reference:

- Atkinson, G. M., Boore, D. M. (2006). Earthquake ground-motion prediction equations for eastern North America, *Bulletin of the Seismological Society of America*, **96:6**, 2181–2205, doi: 10.1785/0120050245.
- Atkinson, G. M., Boore, D. M. (2011). Modifications to existing ground-motion prediction equations in light of new data, *Bulletin of the Seismological Society of America*, **101:3**, 1121-1135, doi: 10.1785/0120100270.

Atkinson & Boore (~~2006~~ 2011): AB06'

New data: SMM events in ENA

M<4, Riviere-du-Loup, Mount Carmel, Val-des-Bois

Modification to AB06:

Magnitude dependent stress drop

Implications:

- Stress drop will be 140 for M 6.5,
  but increases by a factor of 2 to 280 bars at M 5,
  while decreasing by a factor of 2 to 70 bars at M 8.
- Increase in high freq amplitudes at all distances for M<=6,
  decrease for M>=7,
  modest changes for M6-7.

Reference:

- Atkinson, G. M., Boore, D. M. (2006). Earthquake ground-motion prediction equations for eastern North America, *Bulletin of the Seismological Society of America*, **96:6**, 2181–2205, doi: 10.1785/0120050245.
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Atkinson (~~2008~~ AB2011) : A08’

Referenced Empirical Approach (semi-empirical GMPE).

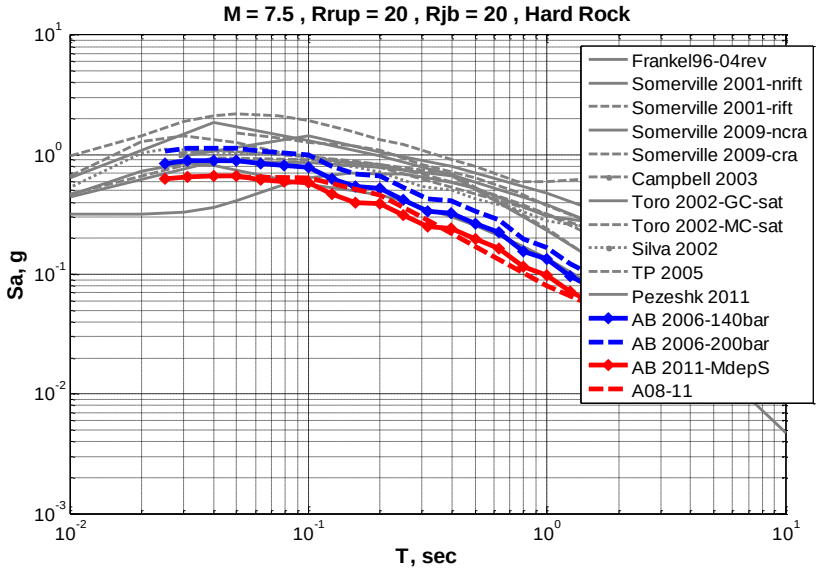
Combines ENA database with BA08 model for reference region of WNA.

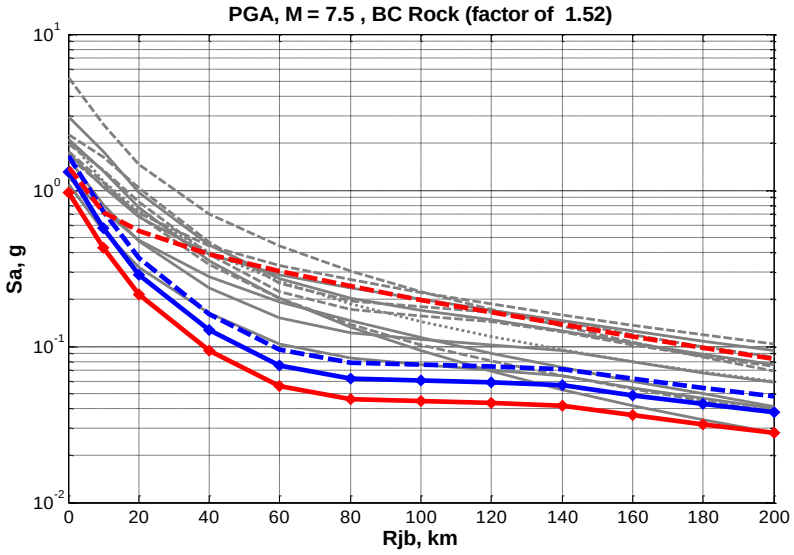
- **Input Parameters:**
  M_w, R_{jb}, T, Vs30, F
- **Site Conditions:**
  Residuals examined for hard rock, adjusted to BC

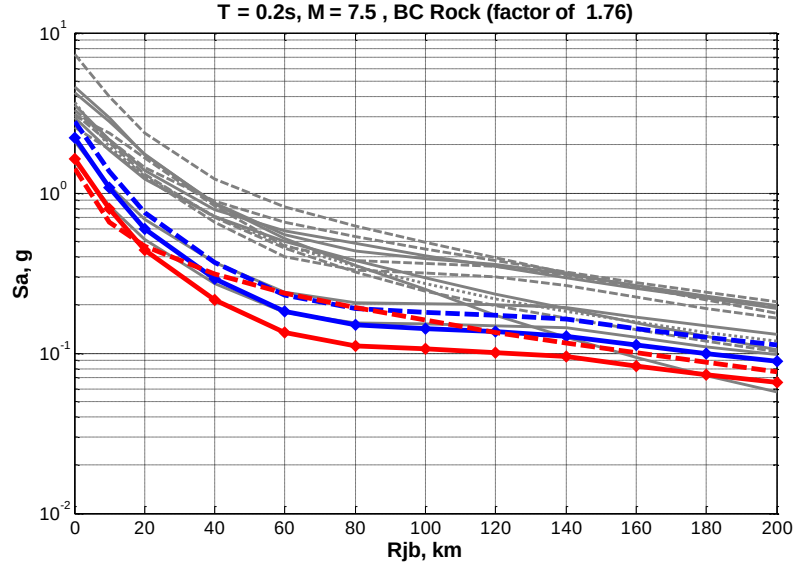
Reference:

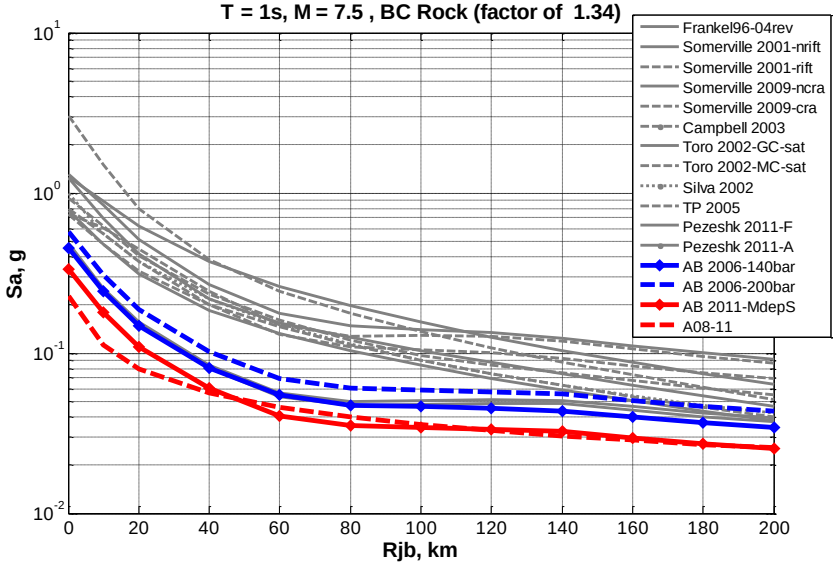
- Atkinson, G. M. (2008). Ground-motion prediction equations for eastern North America from a referenced empirical approach: Implications for epistemic uncertainty, *Bulletin of the Seismological Society of America*, **98:3**, 1304–1318, doi: 10.1785/0120070199.
- Boore, D. M., and G. M. Atkinson (2008). Ground-motion prediction equations for the average horizontal component of PGA, PGV, and 5%-damped PSA at spectral periods between 0.01 s and 10.0 s, Earthquake Spectra 24, 99–138.
- Atkinson, G. M., Boore, D. M. (2011). Modifications to existing ground-motion prediction equations in light of new data, *Bulletin of the Seismological Society of America*, **101:3**, 1121-1135, doi: 10.1785/0120100270.

AB06’ & A08’ (2011): M=7.5





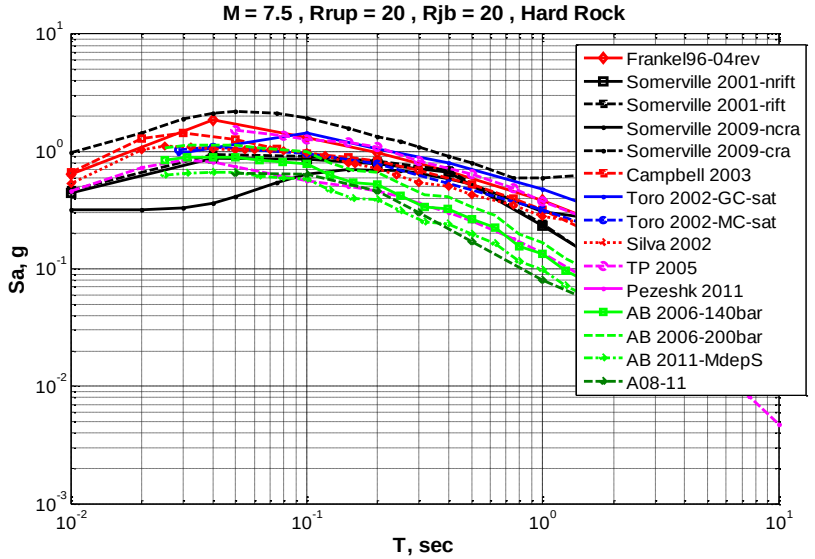


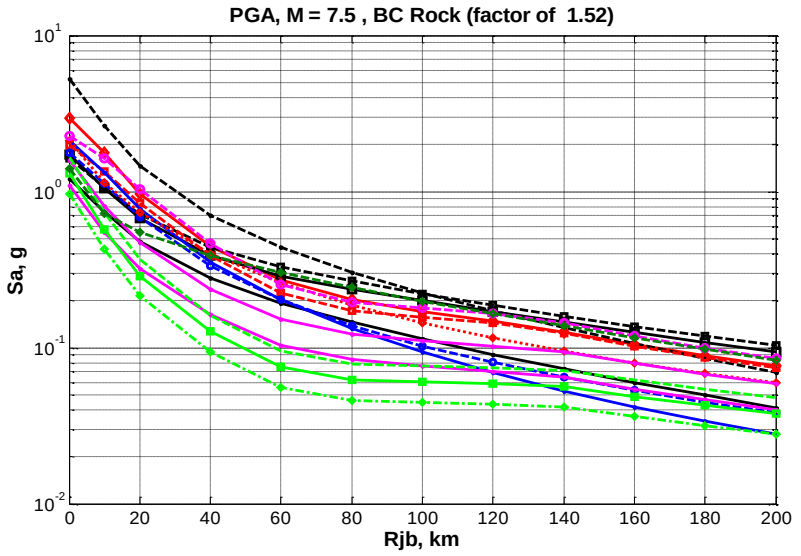


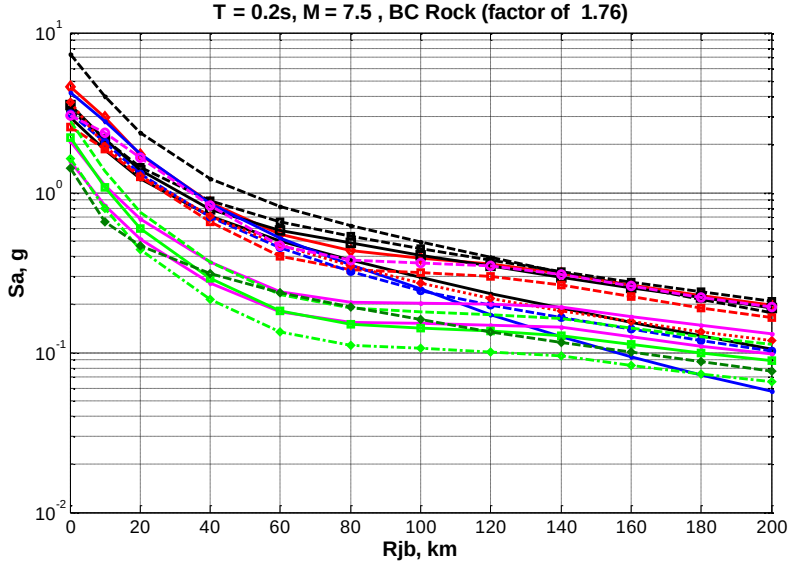
Thank You

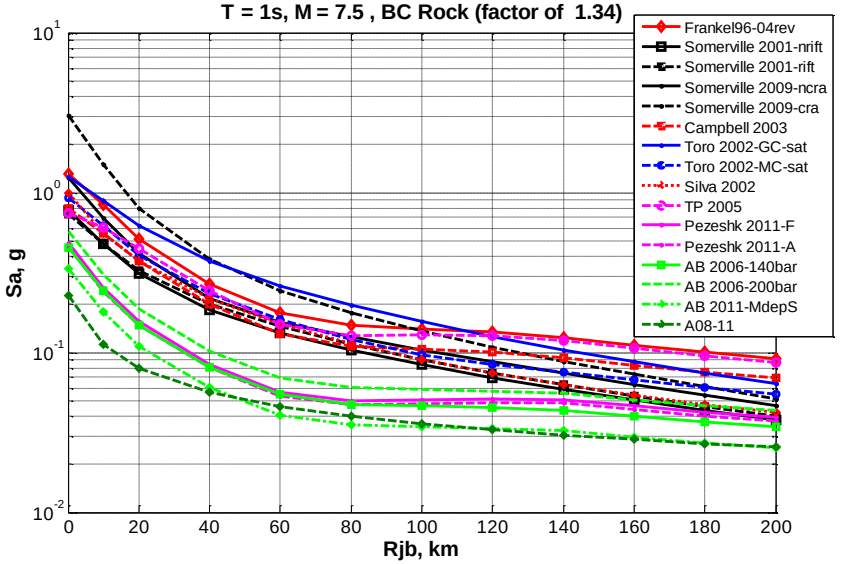
With thanks to Yousef Bozorgnia & Mohammad Javanbarg
for sharing their codes for select GMPEs.

All GMPEs: M=7.5

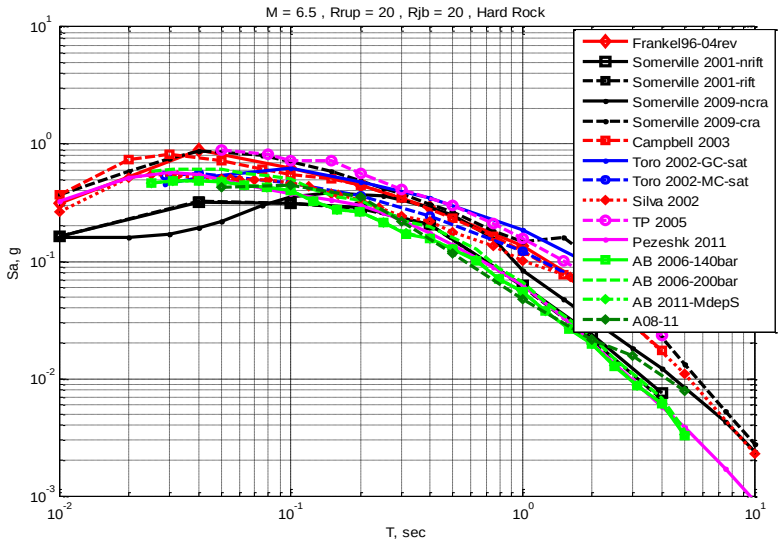


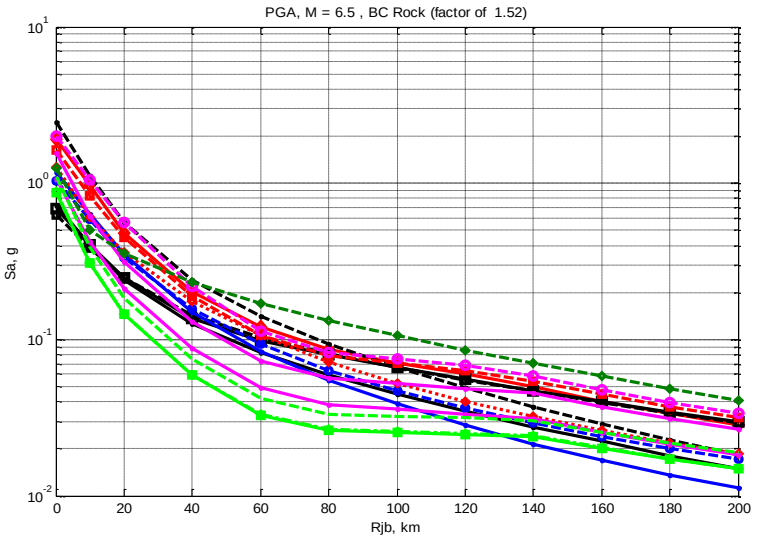


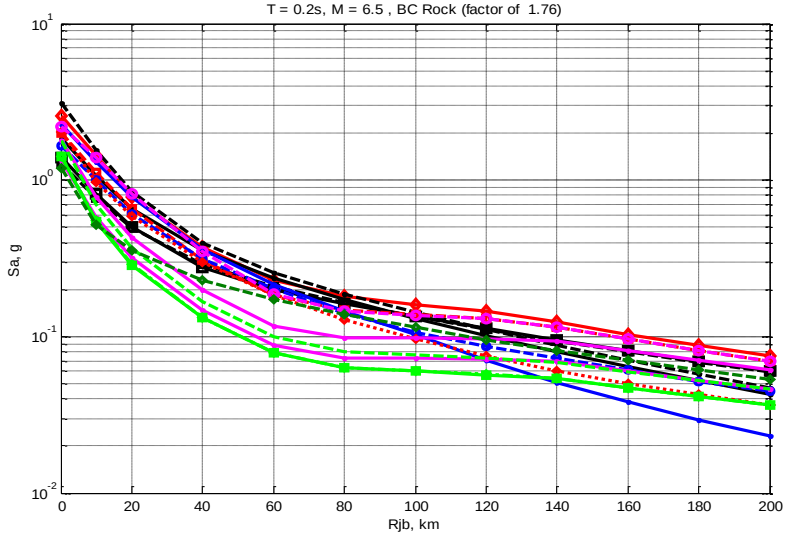


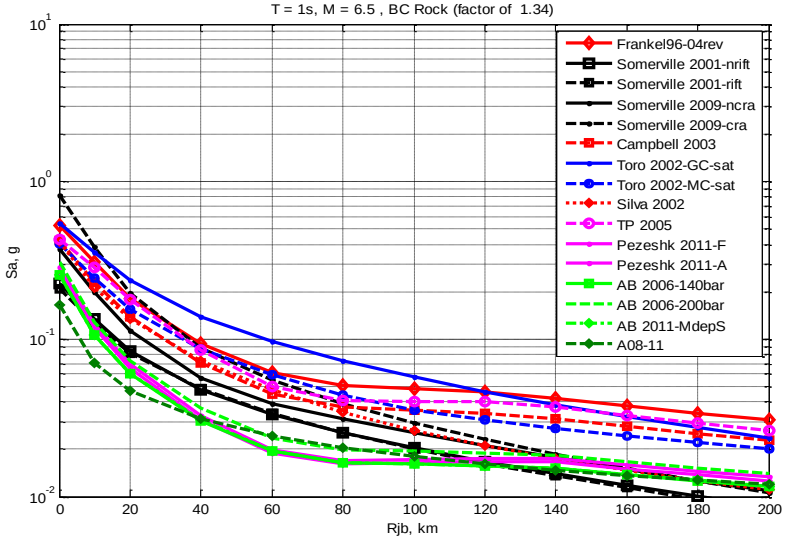


All GMPEs: M=6.5









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