Concerns, Categories, and Weights

A CEUS Workshop Presentation

by Chris Cramer

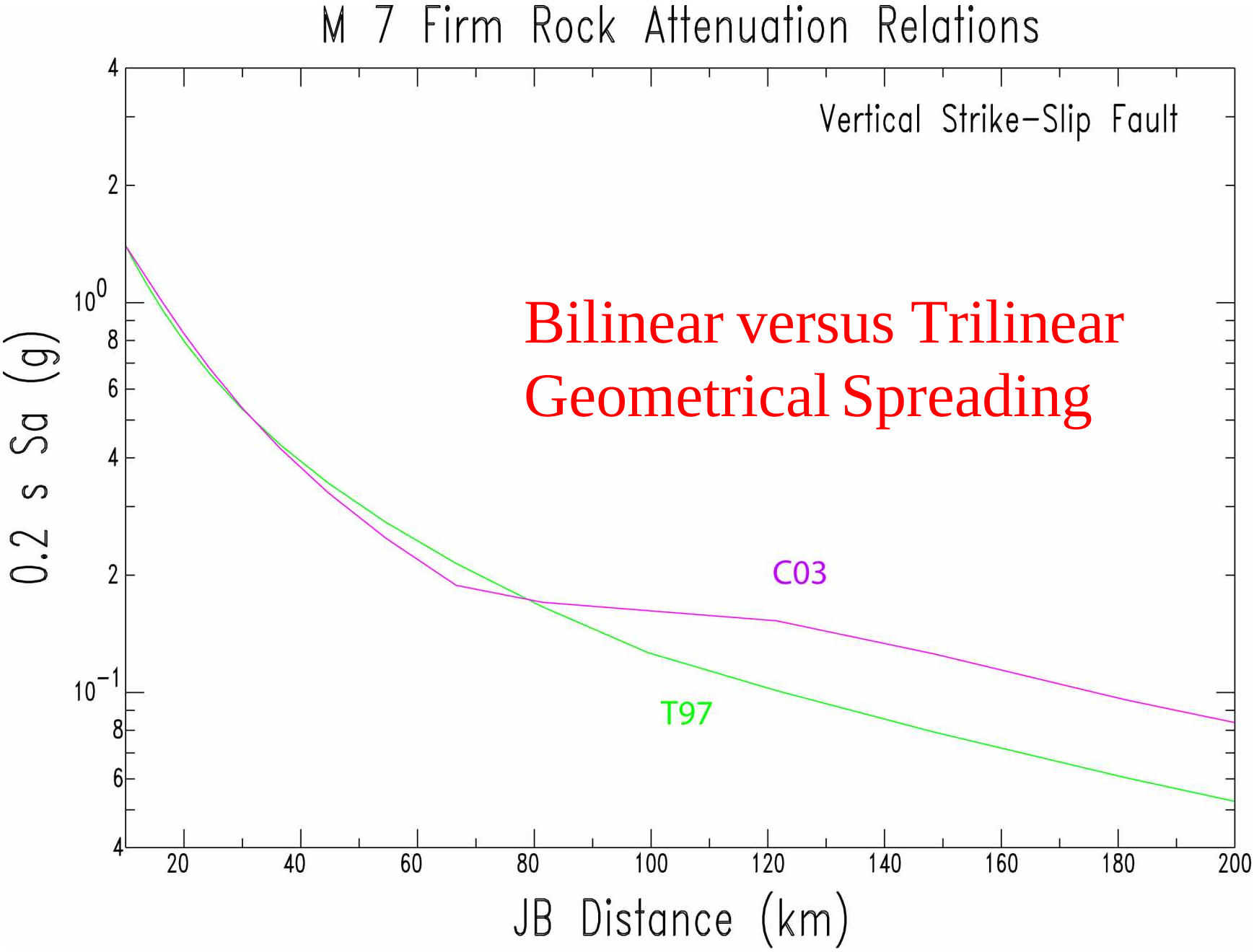
May 10, 2006 at Cambridge, MA

Outline

- Concerns
- Suggested Categories
- Previous Weights

Concerns

- Geometrical Spreading Models
- Crustal Q Models
- Epistemic Uncertainty
- Residual Analysis Results


M 7 Firm Rock Attenuation Relations
Vertical Strike-Slip Fault
Bilinear versus Trilinear
Geometrical Spreading
C03
T97
0.2 s Sa (g)
JB Distance (km)
4
2
10^0
8
6
4
2
10^-1
8
6
4
20
40
60
80
100
120
140
160
180
200

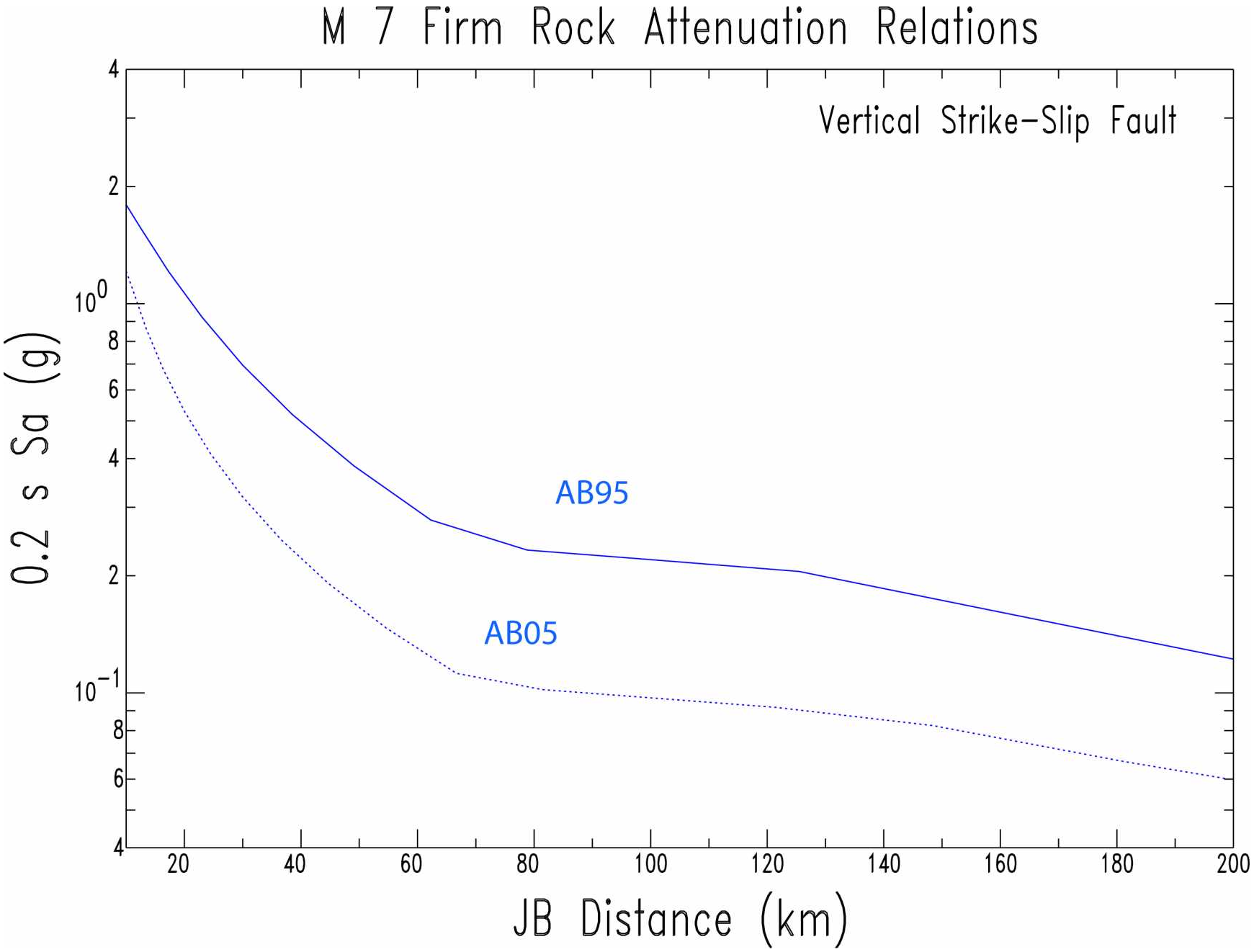
Geometrical Spreading Models

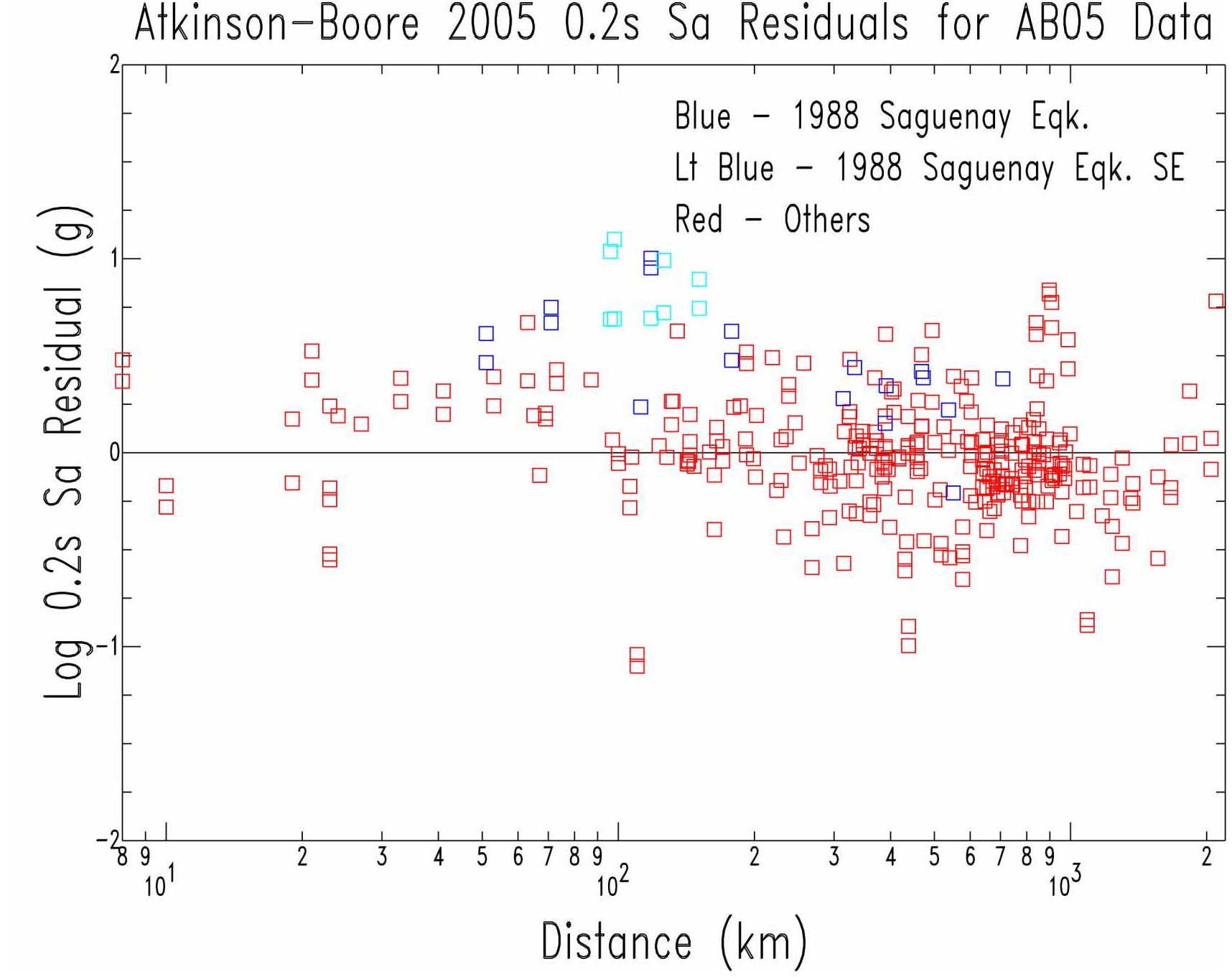
- Bilinear (R^{-1}, $R^{-0.5}$)
  - No Moho bounce (reflection)
  - Implicit Moho bounce (reflection)

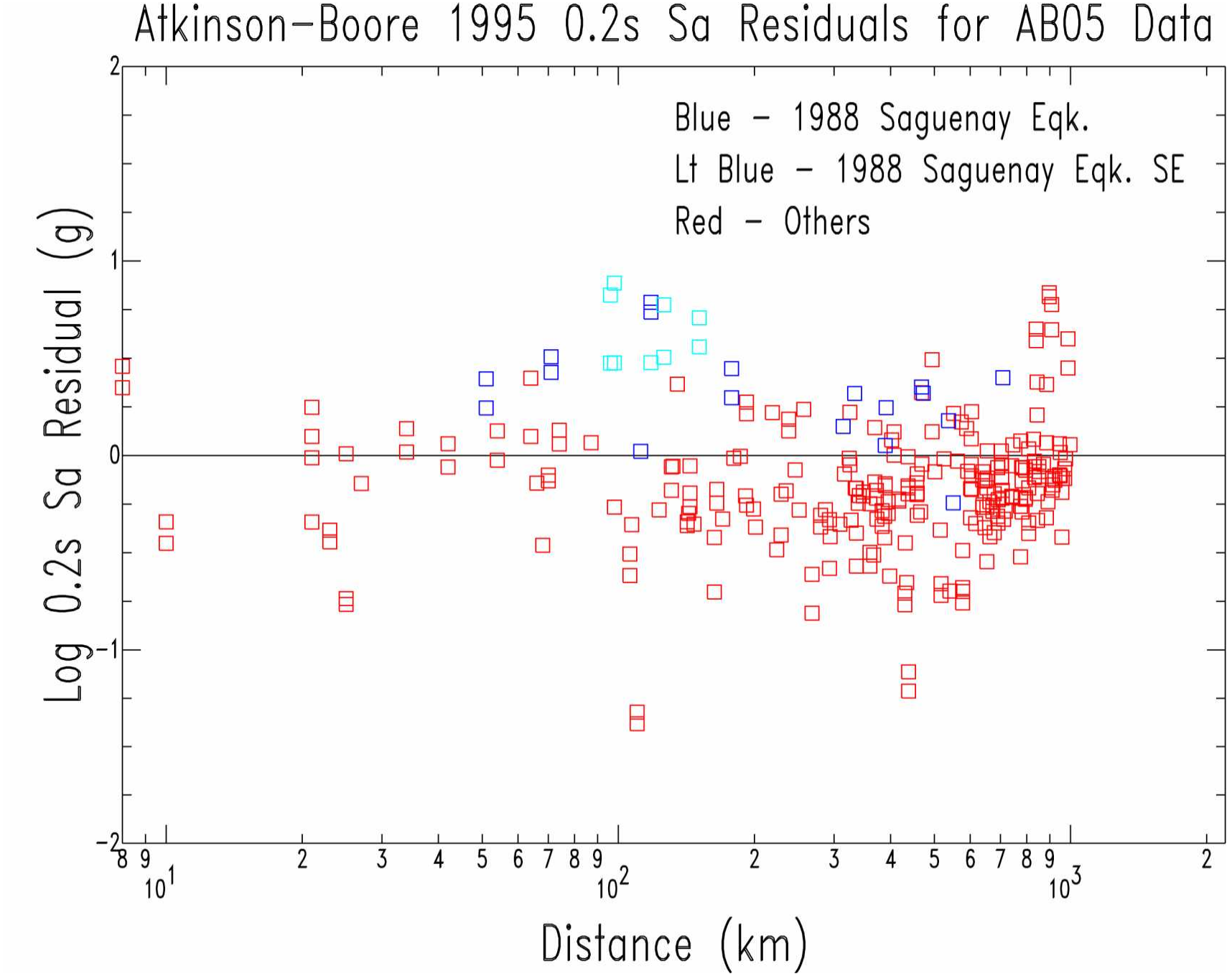
- Trilinear
  - Atkinson and Boore, 1995 (R^{-1}, $R^{0.0}$, $R^{-0.5}$)
  - Atkinson and Boore, 2006 ($R^{-1.3}$, $R^{0.2}$, $R^{-0.5}$)

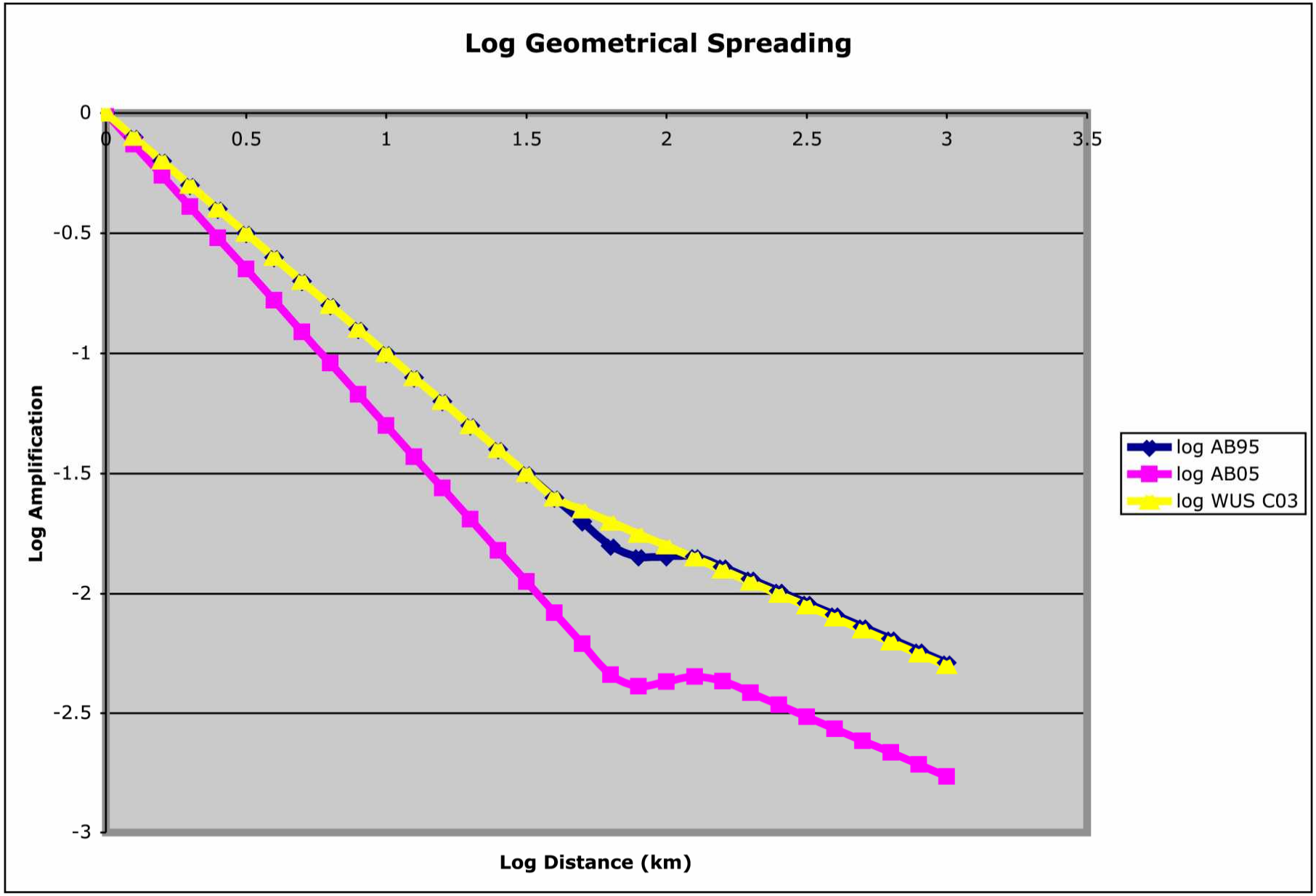
Acceptance

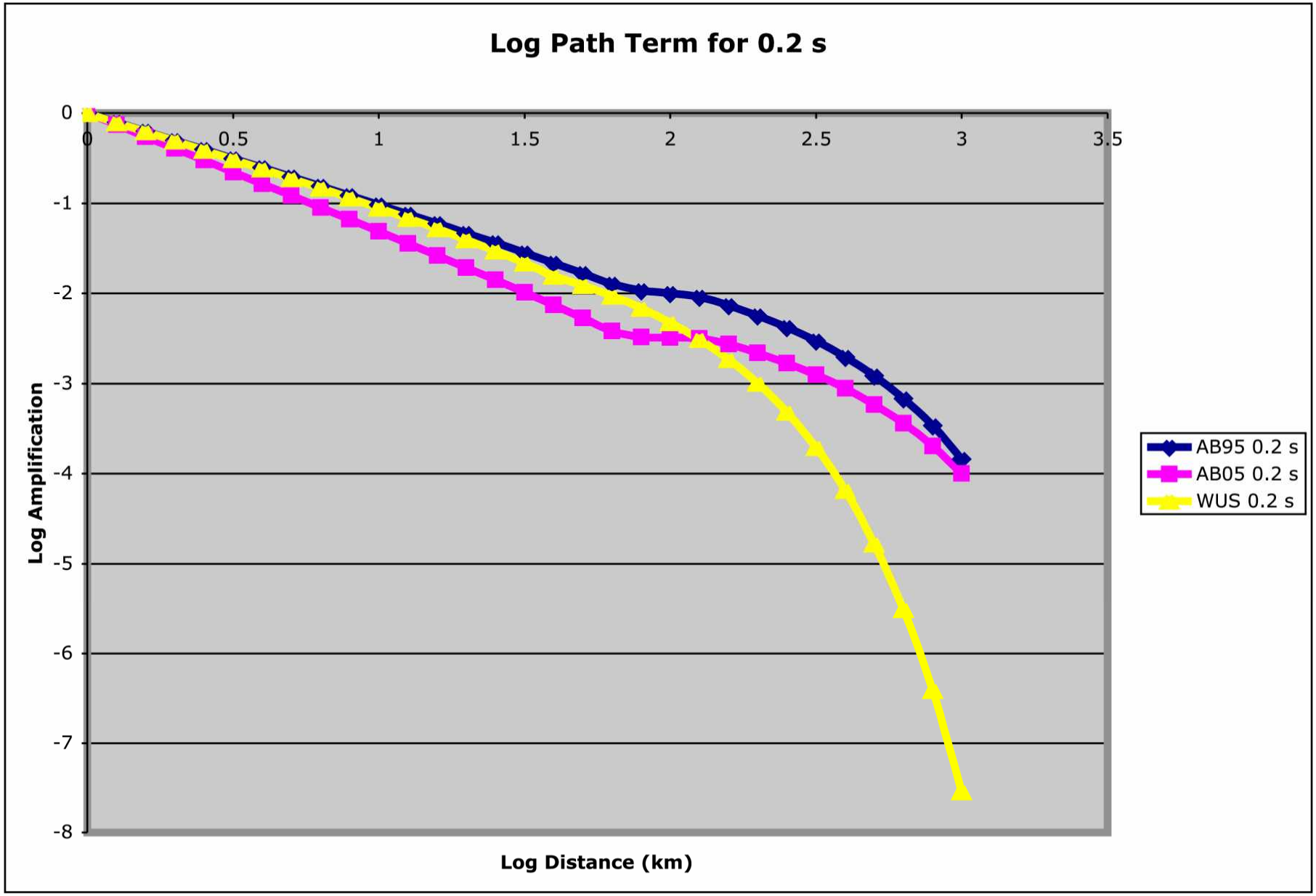
- Both bilinear and trilinear are acceptable alternatives for geometrical spreading.
- What is the problem?


M 7 Firm Rock Attenuation Relations
Vertical Strike-Slip Fault
AB95
AB05
0.2 s Sa (g)
JB Distance (km)
4
2
10^0
8
6
4
2
10^-1
8
6
4
20
40
60
80
100
120
140
160
180
200


Atkinson-Boore 2005 0.2s Sa Residuals for AB05 Data
Blue - 1988 Saguenay Eqk.
Lt Blue - 1988 Saguenay Eqk. SE
Red - Others
Log 0.2s Sa Residual (g)
Distance (km)
2
1
0
-1
-2
8 9
10^1
2 3 4 5 6 7 8 9
10^2
2 3 4 5 6 7 8 9
10^3
2


Atkinson-Boore 1995 0.2s Sa Residuals for AB05 Data
Blue - 1988 Saguenay Eqk.
Lt Blue - 1988 Saguenay Eqk. SE
Red - Others
Log 0.2s Sa Residual (g)
Distance (km)
2
1
0
-1
-2
8 9
10^1
2 3 4 5 6 7 8 9
10^2
2 3 4 5 6 7 8 9
10^3
2


Log Geometrical Spreading
0
-0.5
-1
-1.5
-2
-2.5
-3
0
0.5
1
1.5
2
2.5
3
3.5
Log Amplification
Log Distance (km)
log AB95
log AB05
log WUS C03


Log Path Term for 0.2 s
0
-1
-2
-3
-4
-5
-6
-7
-8
0
0.5
1
1.5
2
2.5
3
3.5
Log Amplification
Log Distance (km)
AB95 0.2 s
AB05 0.2 s
WUS 0.2 s

Concern # 1

- A $R^{-1.3}$ near-source geometrical spreading model for the CEUS may underpredict ground motions in the 30 to 100 km distance range.
- Atkinson and Boore, 2006 lowers high frequency ground motions and hazard ~ 50%.

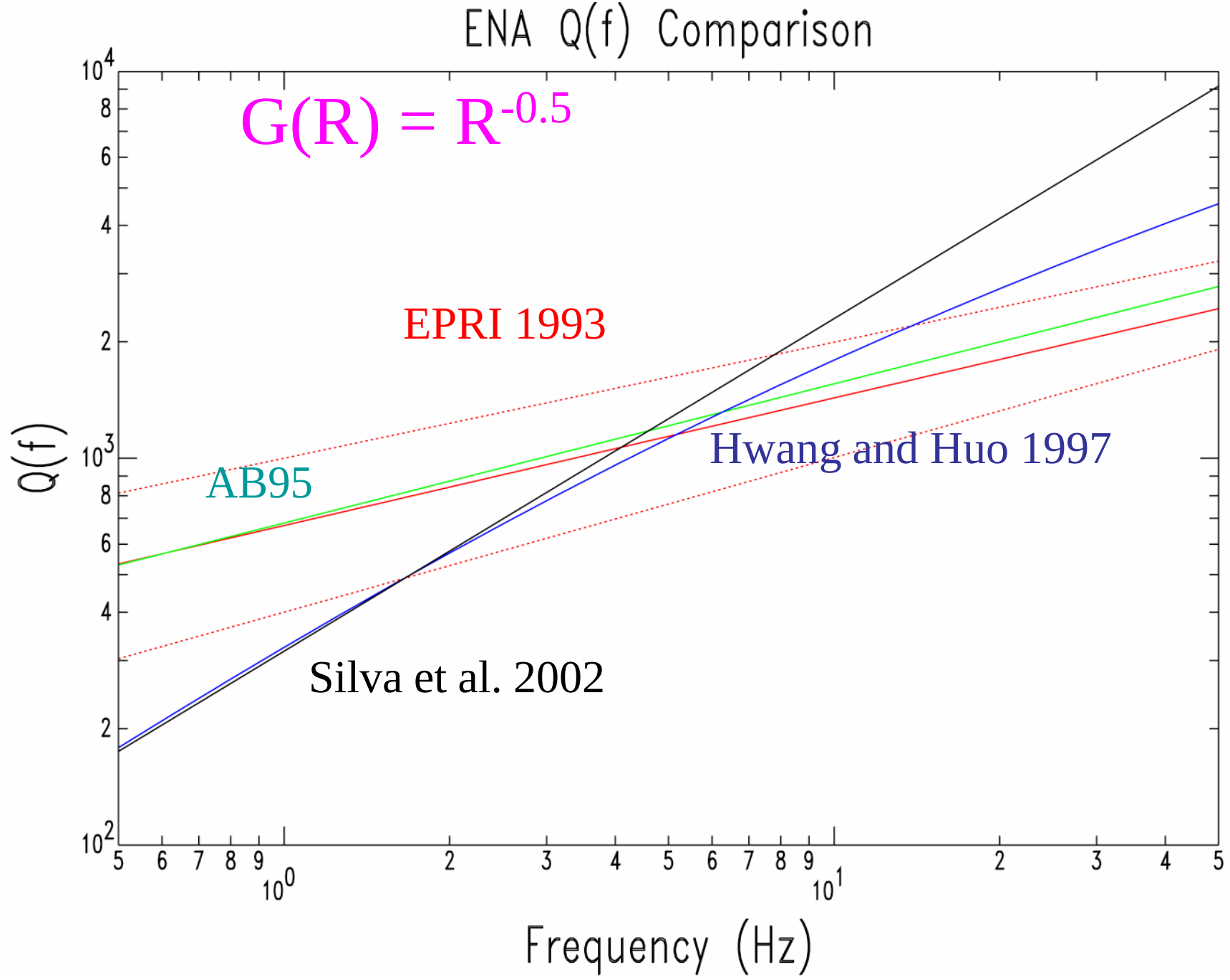
Crustal Q Models

- EPRI (1993) / Atkinson and Boore (1995)
- Silva et al. (1997)

ENA Crustal Q Summary
[Q(f) = Qo*f**eta]

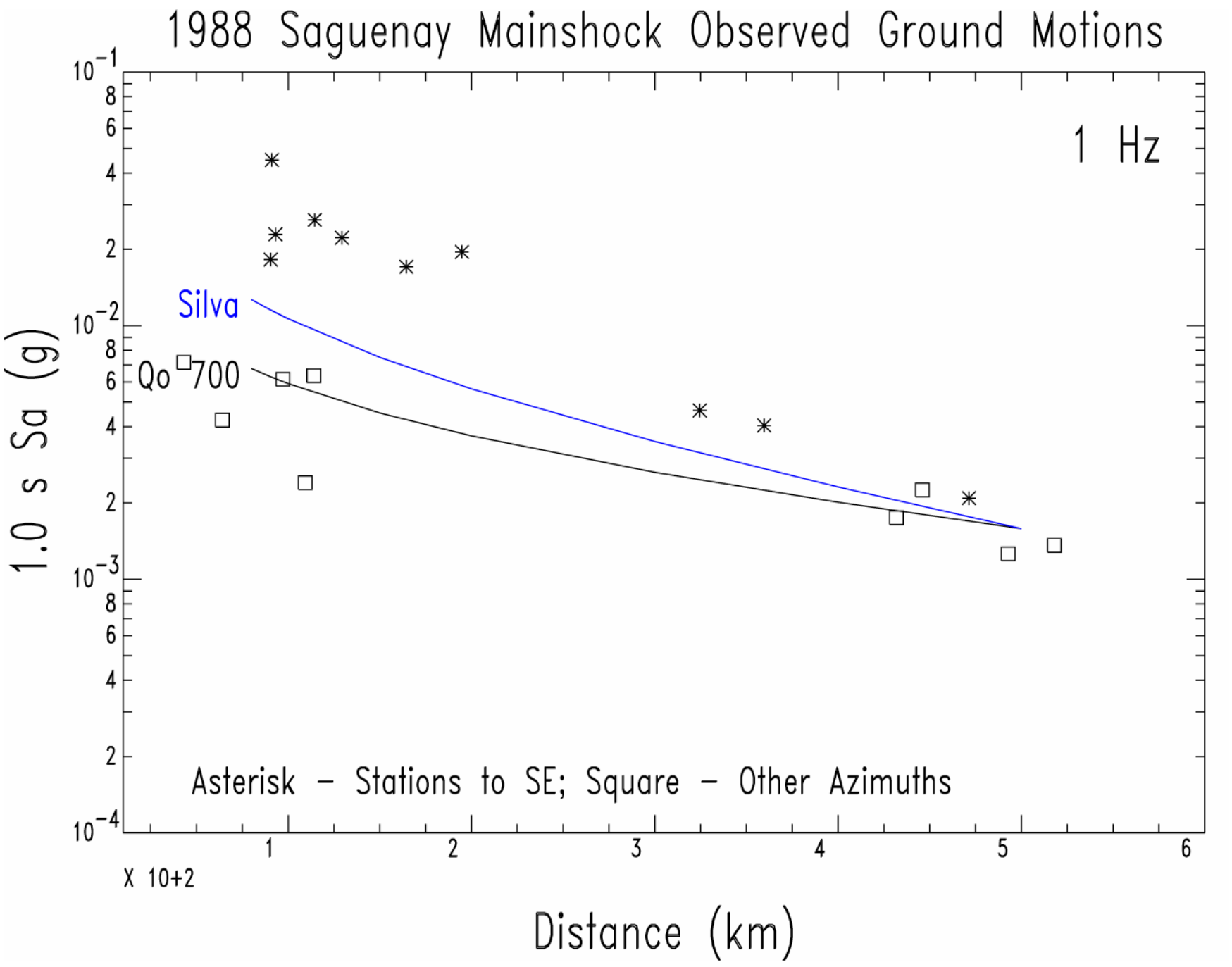
for G (R) = $R^{-0.5}$

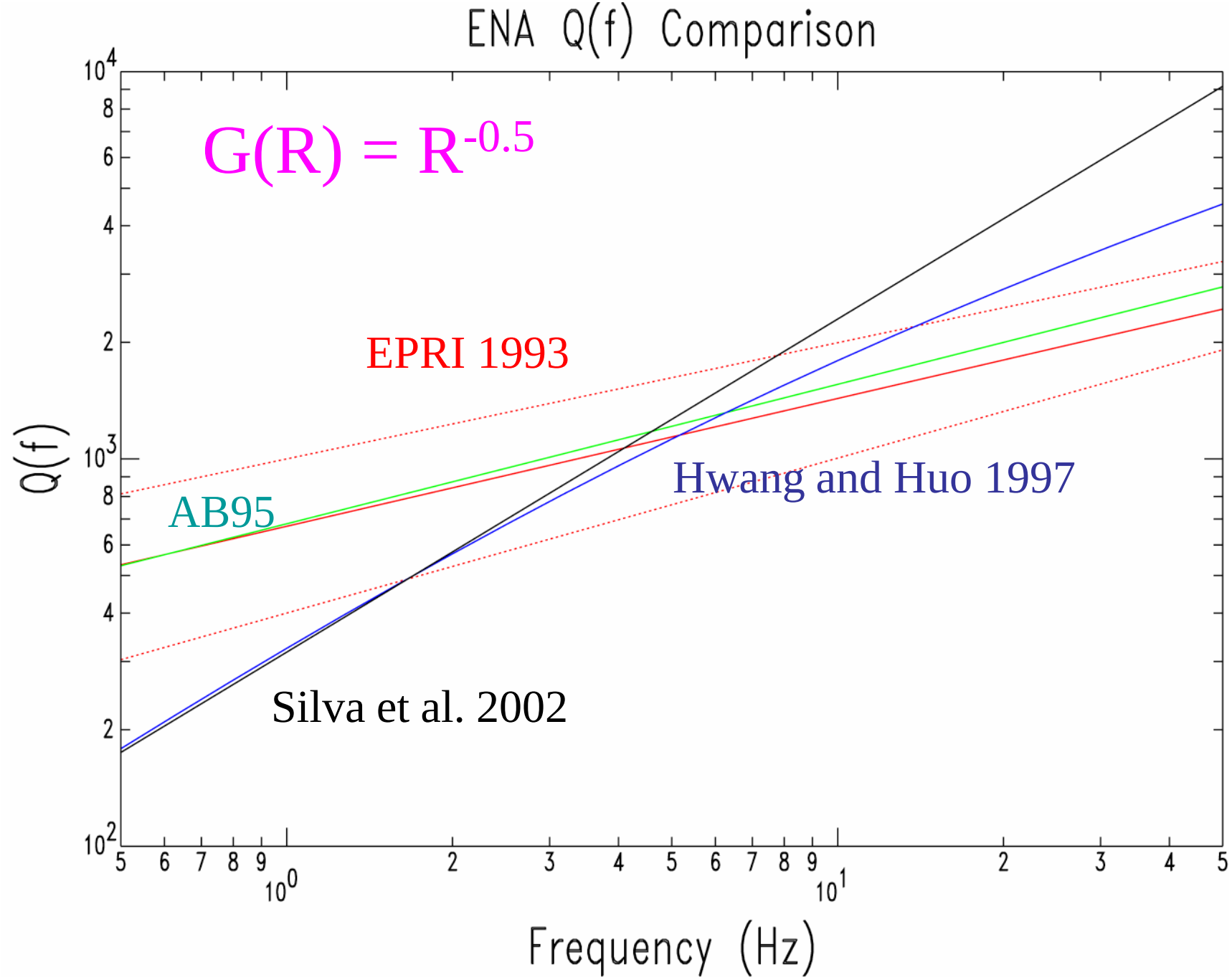
- EPRI (1993):
  - Median: Qo = 670, eta = 0.33
  - Lower Bound: Qo = 400, eta = 0.4
  - Upper Bound: Qo = 1000, eta = 0.3
- Atkinson and Boore (1995):
  - > Qo = 680, eta = 0.36
- Erickson et al. (2004):
  - > Qo = 640±225, eta = 0.34±0.22 (two sigma)

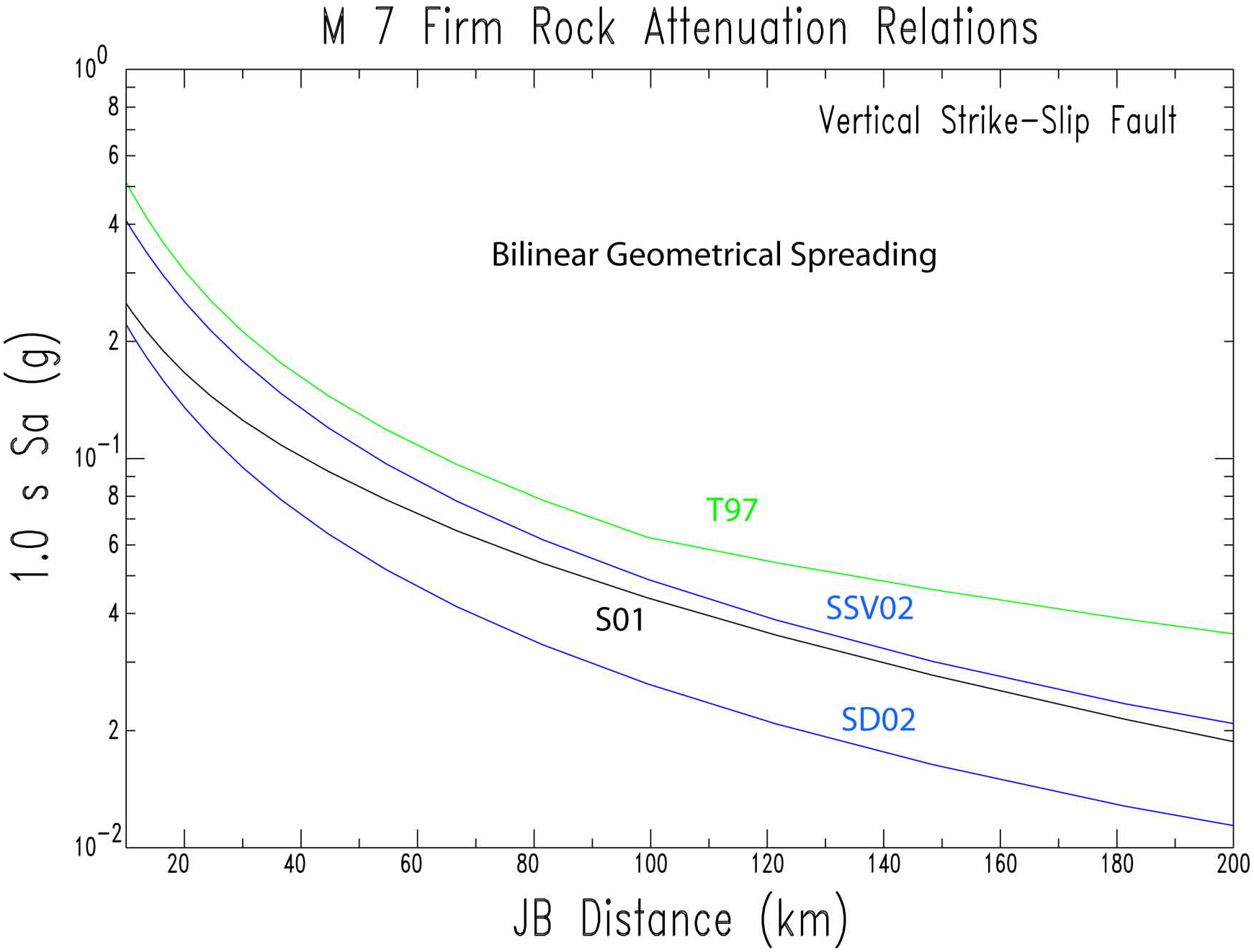

ENA Q(f) Comparison
G(R) = R^-0.5
EPRI 1993
AB95
Hwang and Huo 1997
Silva et al. 2002
Q(f)
Frequency (Hz)

Silva et al. Crustal Q Model

- Median:
  - > Qo = 317, eta = 0.86, $G(R) = R^{-0.5}$ [Qo and eta values exceed Erickson et al. (2004) two sigma range]
- Based on 1988 Saguenay mainshock data
  - Unusually large amplitudes (source effects)
- Boore and Atkinson (1992):
  - Saguenay mainshock amplitudes at 1 Hz are reduced by a factor of two from that expected from a single-corner model (intermediate frequency spectral sag)


1988 Saguenay Mainshock Observed Ground Motions
1 Hz
Silva
Qo 700
Asterisk – Stations to SE; Square – Other Azimuths
1.0 s Sa (g)
X 10+2
Distance (km)


ENA Q(f) Comparison
G(R) = R-0.5
EPRI 1993
AB95
Hwang and Huo 1997
Silva et al. 2002
Q(f)
Frequency (Hz)


M 7 Firm Rock Attenuation Relations
Vertical Strike-Slip Fault
Bilinear Geometrical Spreading
T97
SSV02
S01
SD02
1.0 s Sa (g)
JB Distance (km)
10^0
8
6
4
2
10^-1
8
6
4
2
10^-2
20
40
60
80
100
120
140
160
180
200

Concern # 2:

- Due to their crustal Q model the Silva et al. (2002, 2003) single corner relations behave more like single corner relations at close in distances (< 80 km) but more like double corner relations at greater distances.
- Similarly the Silva et al. (2002, 2003) double corner relations seem to overestimate or double count the double corner effect at larger distances (> 80 km).
- Significantly lowers 1 Hz ground motion hazard by ~ 50%.

Handling Epistemic Uncertainty

- Relations with median prediction equations
  - Use Median Only?
  - Add plus/minus 2X median alternatives?

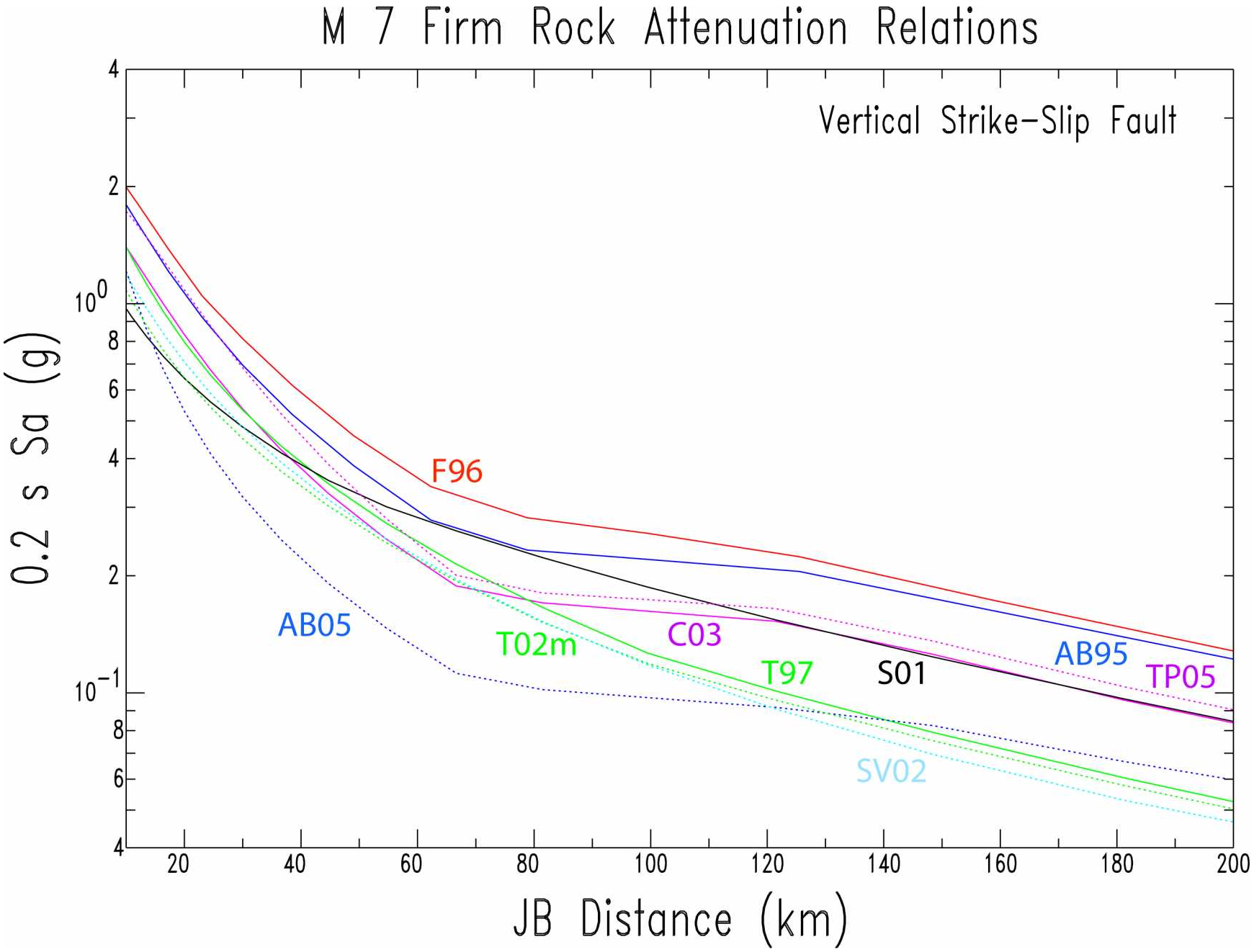
- Relations with explicit alternatives
  - Use Median Only?
  - Use Low, Median, and High alternatives?

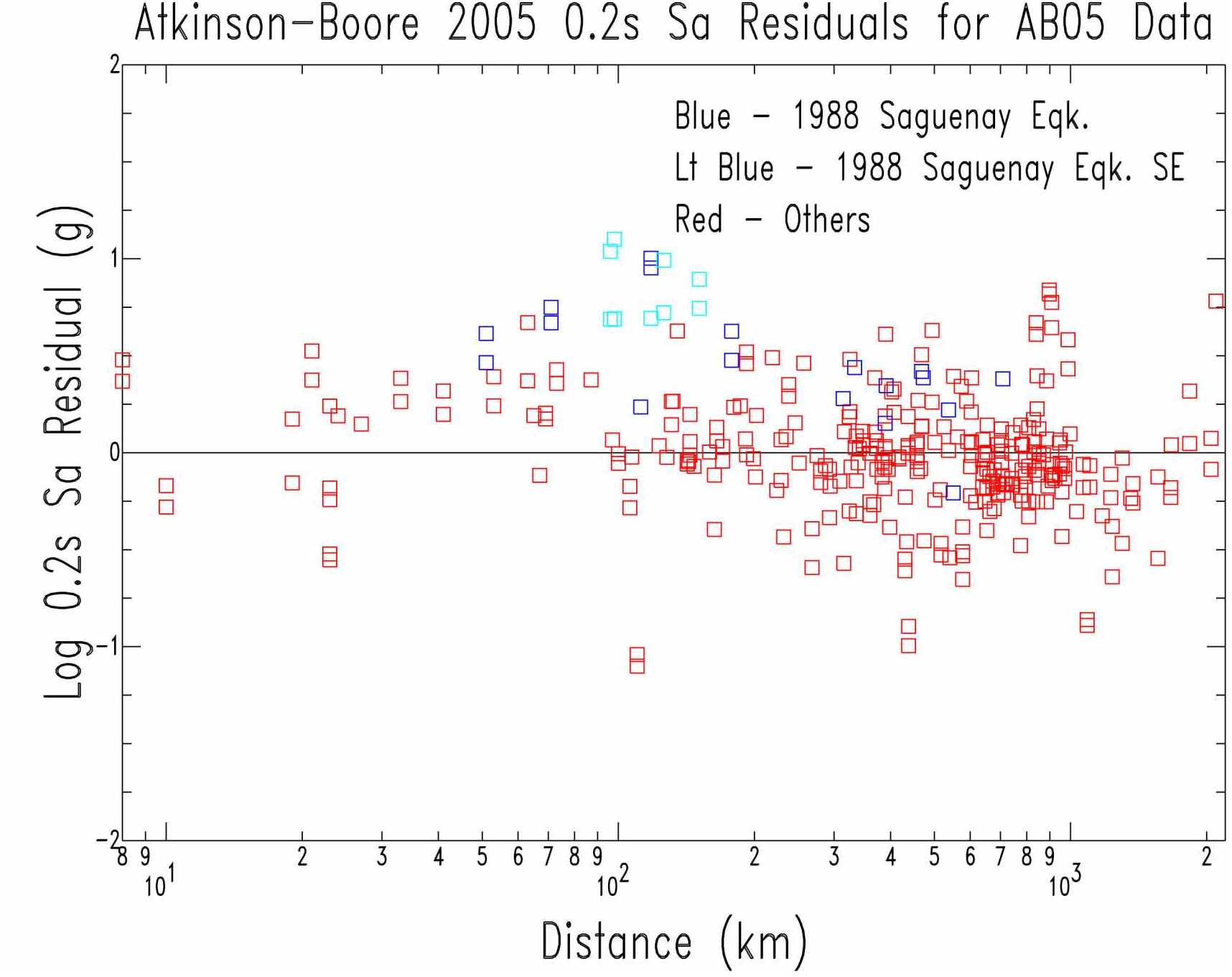
Concern # 3

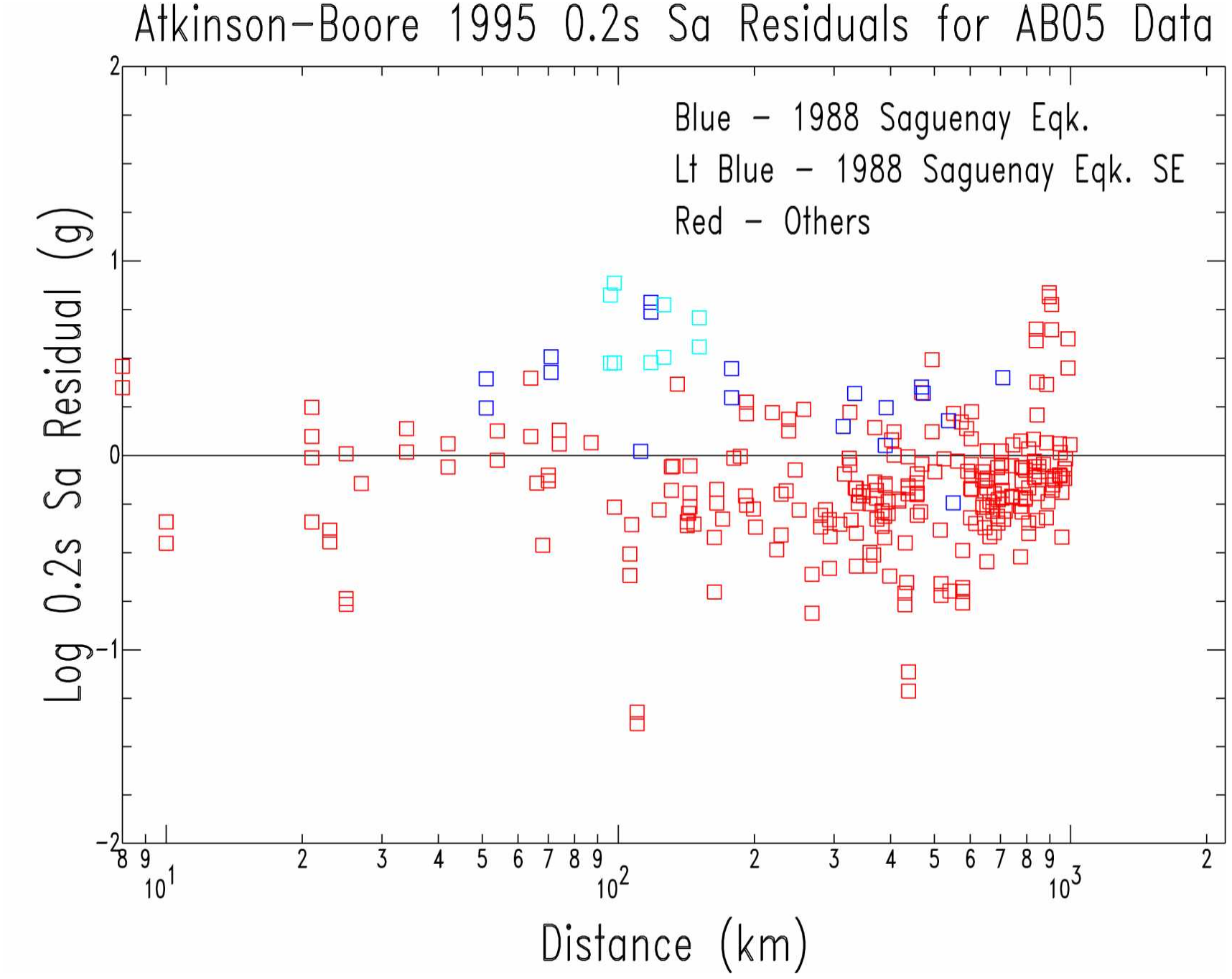
- How should epistemic uncertainty in ground motion prediction equations be represented in the national seismic hazard maps? Is the variability among median relations sufficient?

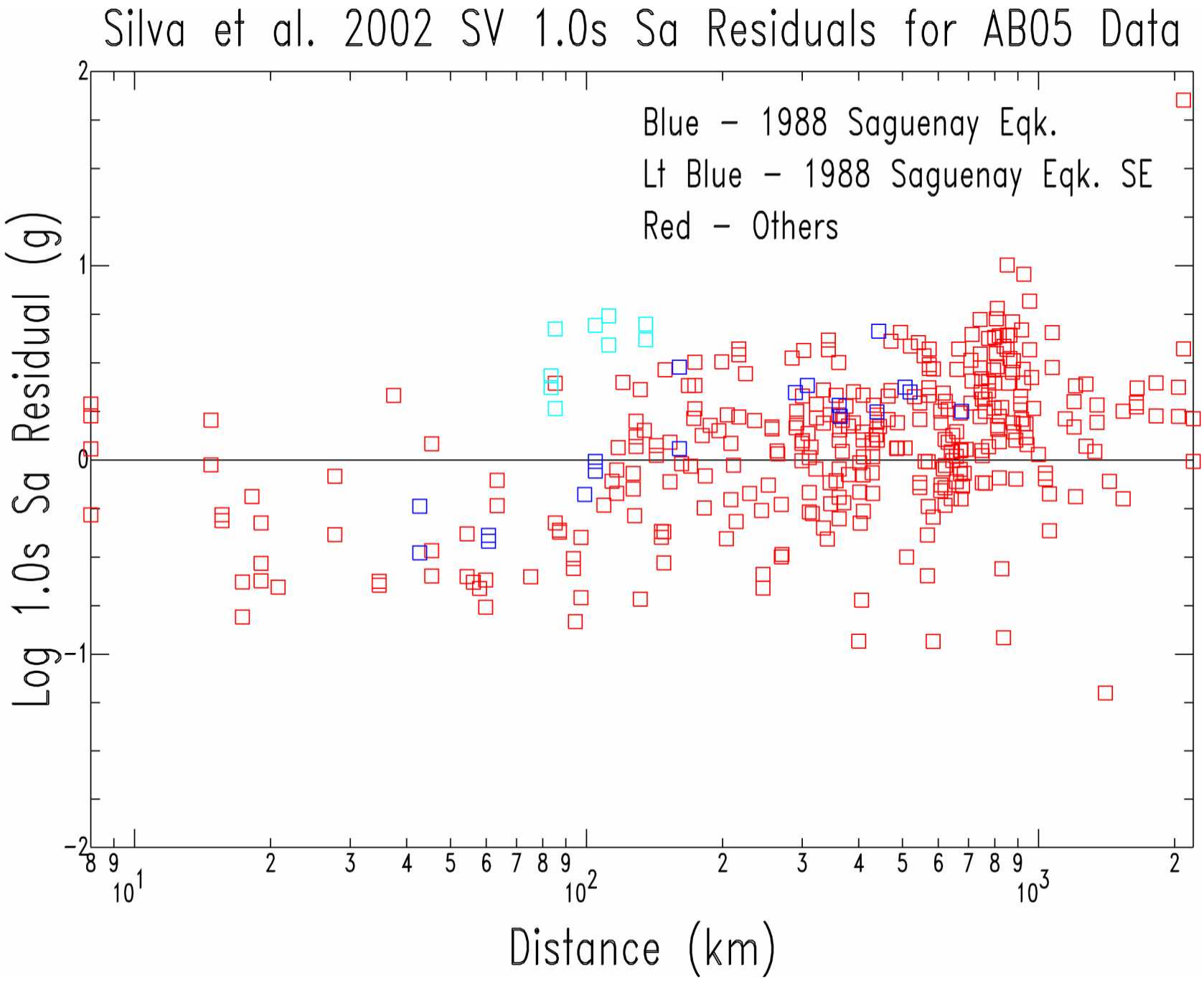
Residual Analysis Summary

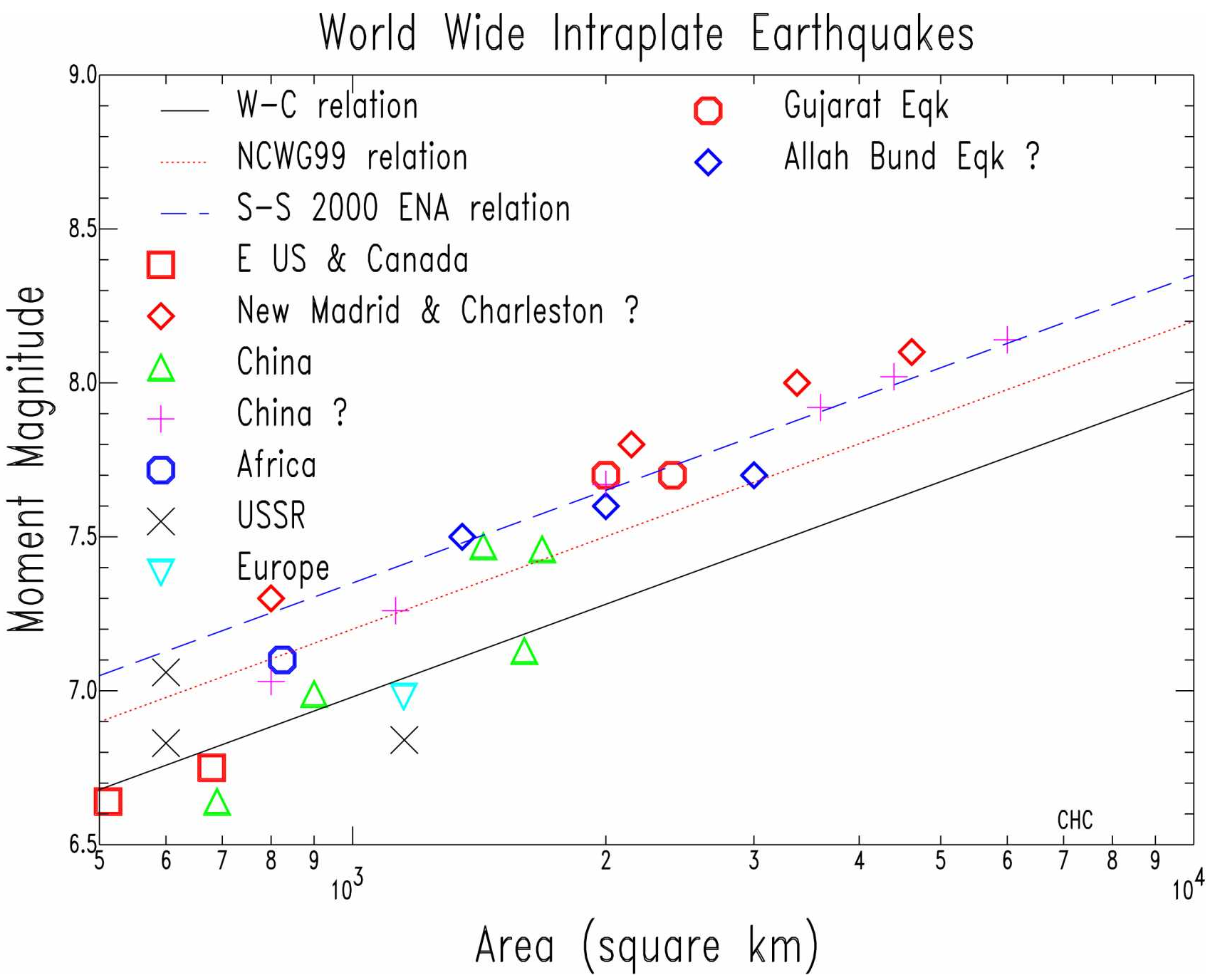
- Residual analysis results reflect observations seen in comparison plots plus our concerns with unusual path models.
- Seismic hazard in CEUS is controlled by the rate of M7s, particularly in higher hazard areas. Observations are rare for these large magnitudes and in general for distances less than 100 km.


M 7 Firm Rock Attenuation Relations
Vertical Strike-Slip Fault
0.2 s Sa (g)
JB Distance (km)
F96
AB05
T02m
C03
T97
S01
AB95
TP05
SV02
4
2
10^0
8
6
4
2
10^-1
8
6
4
20
40
60
80
100
120
140
160
180
200


Atkinson-Boore 2005 0.2s Sa Residuals for AB05 Data
Blue - 1988 Saguenay Eqk.
Lt Blue - 1988 Saguenay Eqk. SE
Red - Others
Log 0.2s Sa Residual (g)
Distance (km)
2
1
0
-1
-2
8 9
10^1
2 3 4 5 6 7 8 9
10^2
2 3 4 5 6 7 8 9
10^3
2


Atkinson-Boore 1995 0.2s Sa Residuals for AB05 Data
Blue - 1988 Saguenay Eqk.
Lt Blue - 1988 Saguenay Eqk. SE
Red - Others
Log 0.2s Sa Residual (g)
Distance (km)
2
1
0
-1
-2
8 9
10^1
2 3 4 5 6 7 8 9
10^2
2 3 4 5 6 7 8 9
10^3
2


Silva et al. 2002 SV 1.0s Sa Residuals for AB05 Data
Blue - 1988 Saguenay Eqk.
Lt Blue - 1988 Saguenay Eqk. SE
Red - Others
Log 1.0s Sa Residual (g)
Distance (km)
2
1
0
-1
-2
8 9
10^1
2 3 4 5 6 7 8 9
10^2
2 3 4 5 6 7 8 9
10^3
2


World Wide Intraplate Earthquakes
W-C relation
NCWG99 relation
S-S 2000 ENA relation
E US & Canada
New Madrid & Charleston ?
China
China ?
Africa
USSR
Europe
Gujarat Eqk
Allah Bund Eqk ?
Moment Magnitude
9.0
8.5
8.0
7.5
7.0
6.5
5
6
7
8
9
10^3
2
3
4
5
6
7
8
9
10^4
Area (square km)
CHC

Concern # 4 (last)

- Should the residual analysis results influence weighting? Is there enough observations?

- What about a magnitude and/or distance component in the weighting to reflect the influence of larger earthquakes and closer distances in seismic hazard calculations?

Categories for Relations

- Single-Corner Point-Source:
  - Toro et al., 1997 + 2002 updates
  - Frankel et al., 1996 + 2006 updates
- Double-Corner Point-Source:
  - Atkinson and Boore, 1995
- Hybrid Empirical:
  - Campbell, 2003
  - Tavakoli and Pezeshk, 2005
- Finite Fault:
  - Somerville et al., 2001 (M > 6 only)
  - Atkinson and Boore, 2006
- Distinctive Path Model:
  - Silva et al., 2003 Single Corner
  - Silva et al., 2003 Double Corner

2002 Weights

- 0.25 for
  - Atkinson and Boore, 1995
  - Frankel et al., 1996
  - Toro et al., 1997

- 0.125 for
  - Somerville et al., 2001*
  - Campbell, 2003

* Not used below M 6.0, remaining weights renormalized