NGA versus Earlier Models:
(0) Effects on WUS PSHA, 2%50
(1) Epistemic Uncertainty
(2) Rock and Soil

Steve Harmsen, USGS

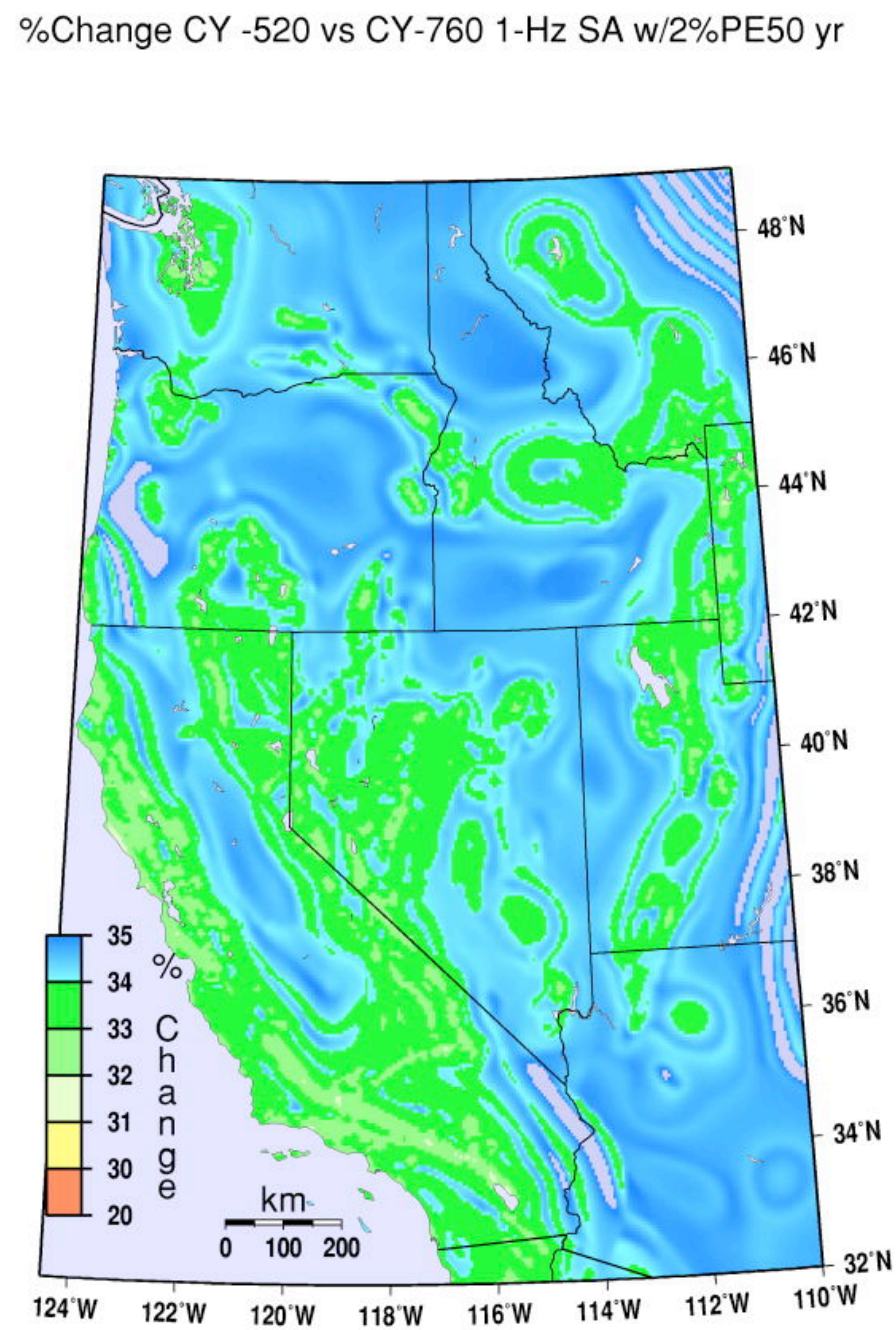
September 2006

The reference rock condition

- What is the effect of using reference Vs30 of 520 m/s instead of 760 m/s?
- Answer1: At PE= 2%/50, over 30% up for 1-s SA
- Answer5: At PE= 2%/50, 2% to 20% up for 0.2-s SA
- Probabilistic ground motions do not increase linearly with decrease in Vs30, but the increase is generally quite significant for WUS sites & crustal sources.

1-s Spectral Acceleration
Chiou-Youngs SiteAmp

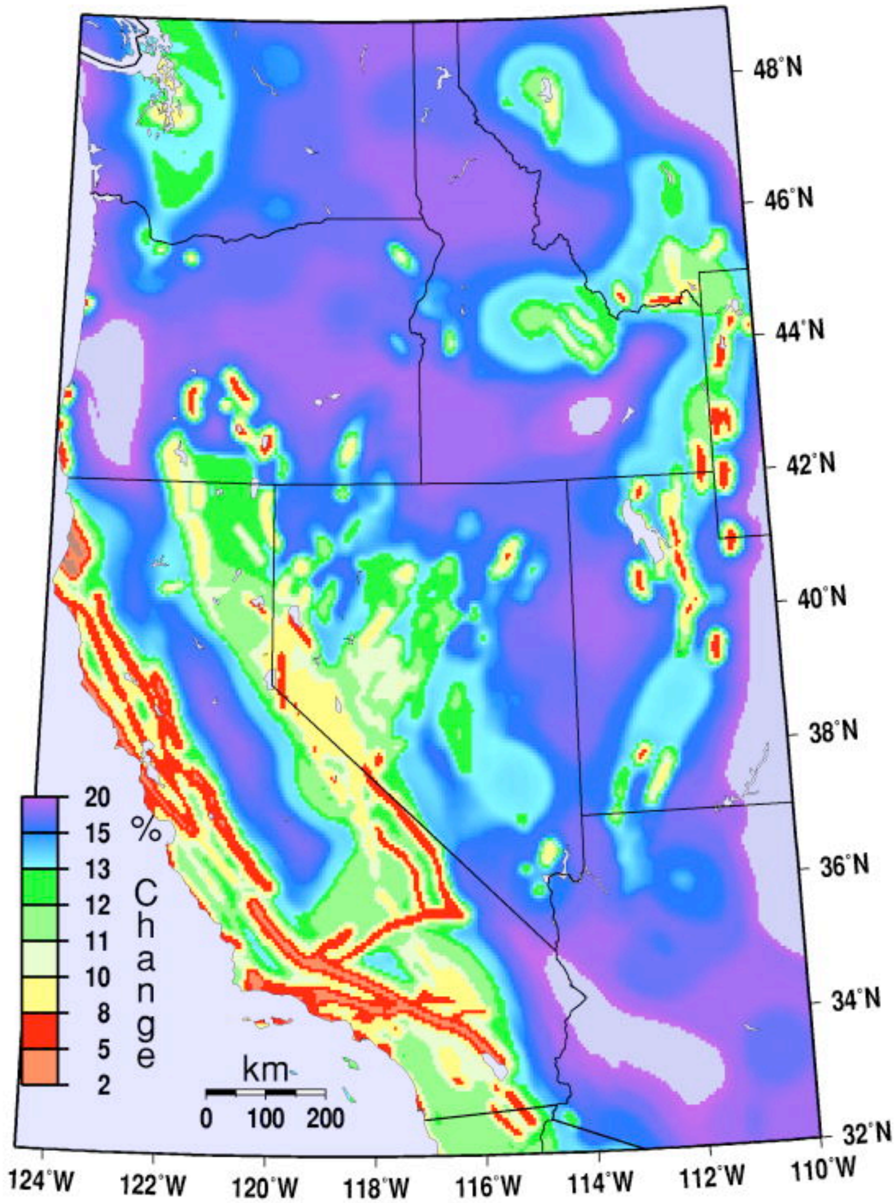
Changing Vref from 760 m/s to 520 yields about 33% incr. Limited nonlinear siteamp in CY relation at 520 m/s. Nonlinear effect reduces ground motion at sites over the most active faults compared to what a linear siteamp function would produce. Other relations such as CB claim linear siteamp at 520 m/s for 1-s SA.



5 Hz 520/760

- Changing Vref has small effect over active faults
- Large effect over less seismically active regions
- Sig. nonlinear siteamp in CY& CB at 520 m/s

%Change CY Vs520 vs CY Vs760 5-Hz SA w/2%PE50 yr



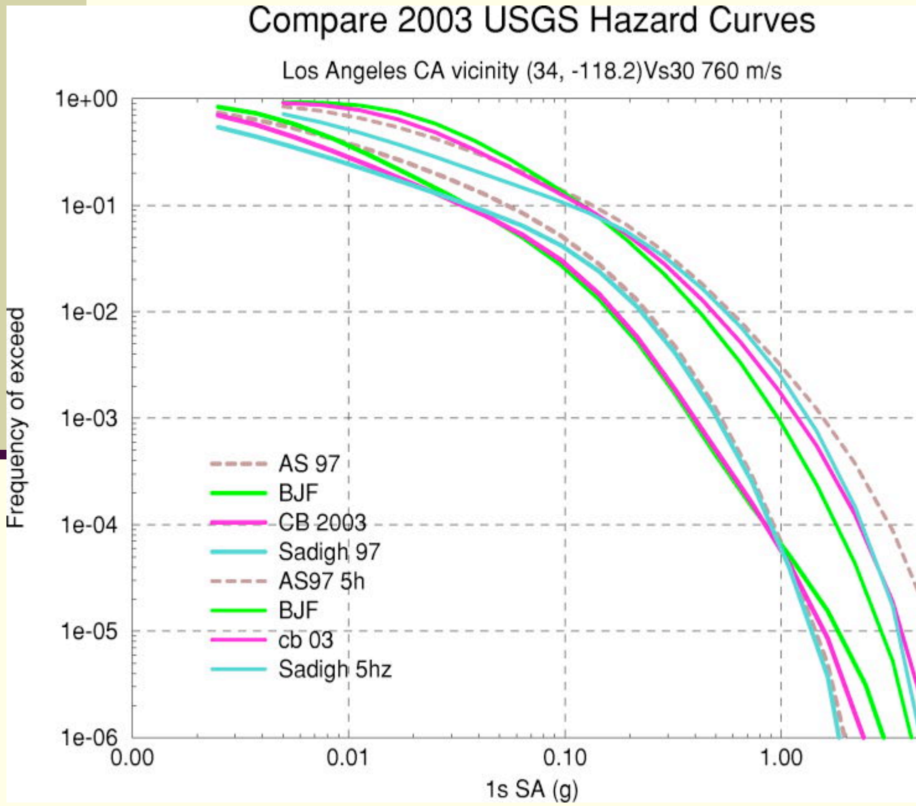
GMT Sep 23 09:30 PRELIM PSHA WUS crustal sources. Site 520ms/Site 760. 5 Hz 2% in 50 yr PE. Use Chiou-Youngs 9/2006

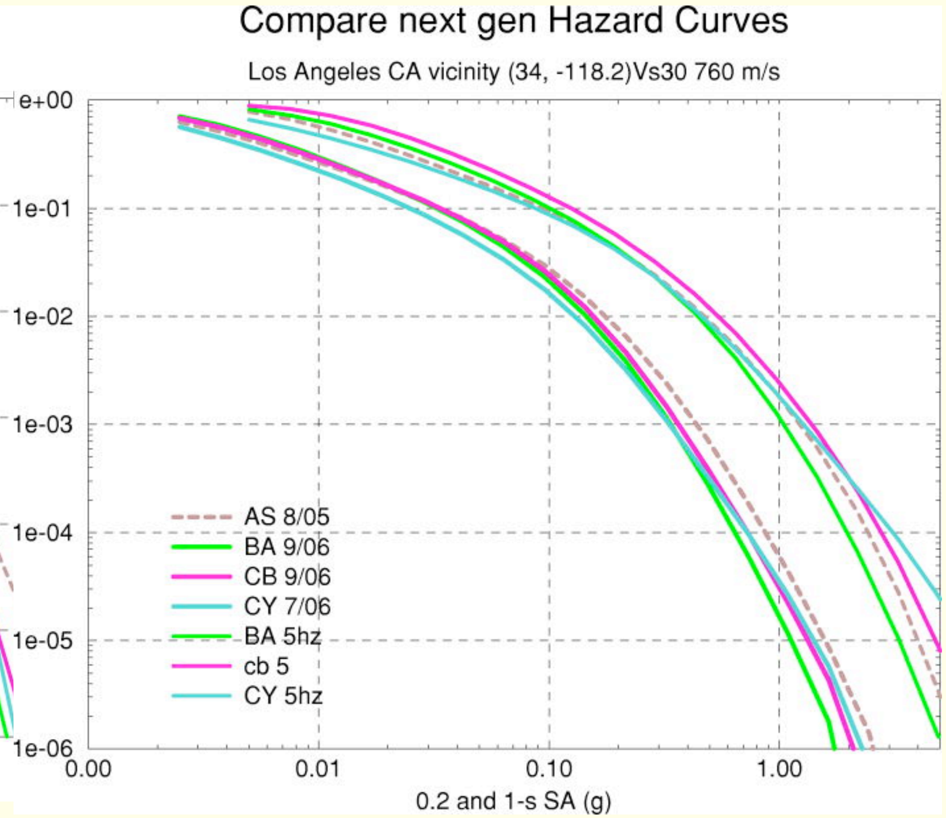
How does new epistemic uncertainty compare with previous?

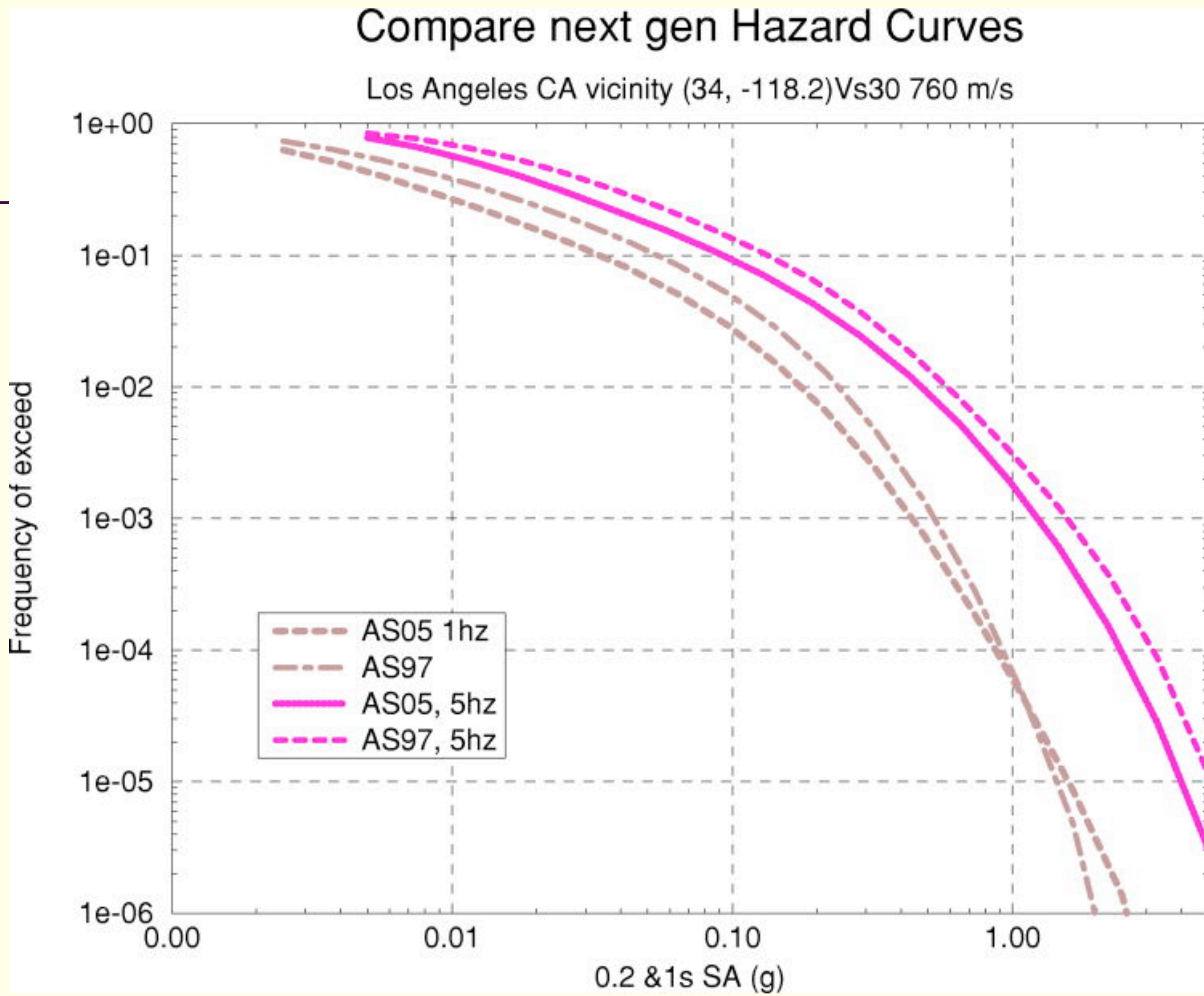
- Consider range of hazard curves using new relations
- Compare with range of hazard curves using 2003 relations
- Consider special cases: active thrust faults with site on hanging wall.
- Look at several cities to see if “low” NGA variability is a fact or a myth.
- Need to do more but these examples suggest myth rather than fact.

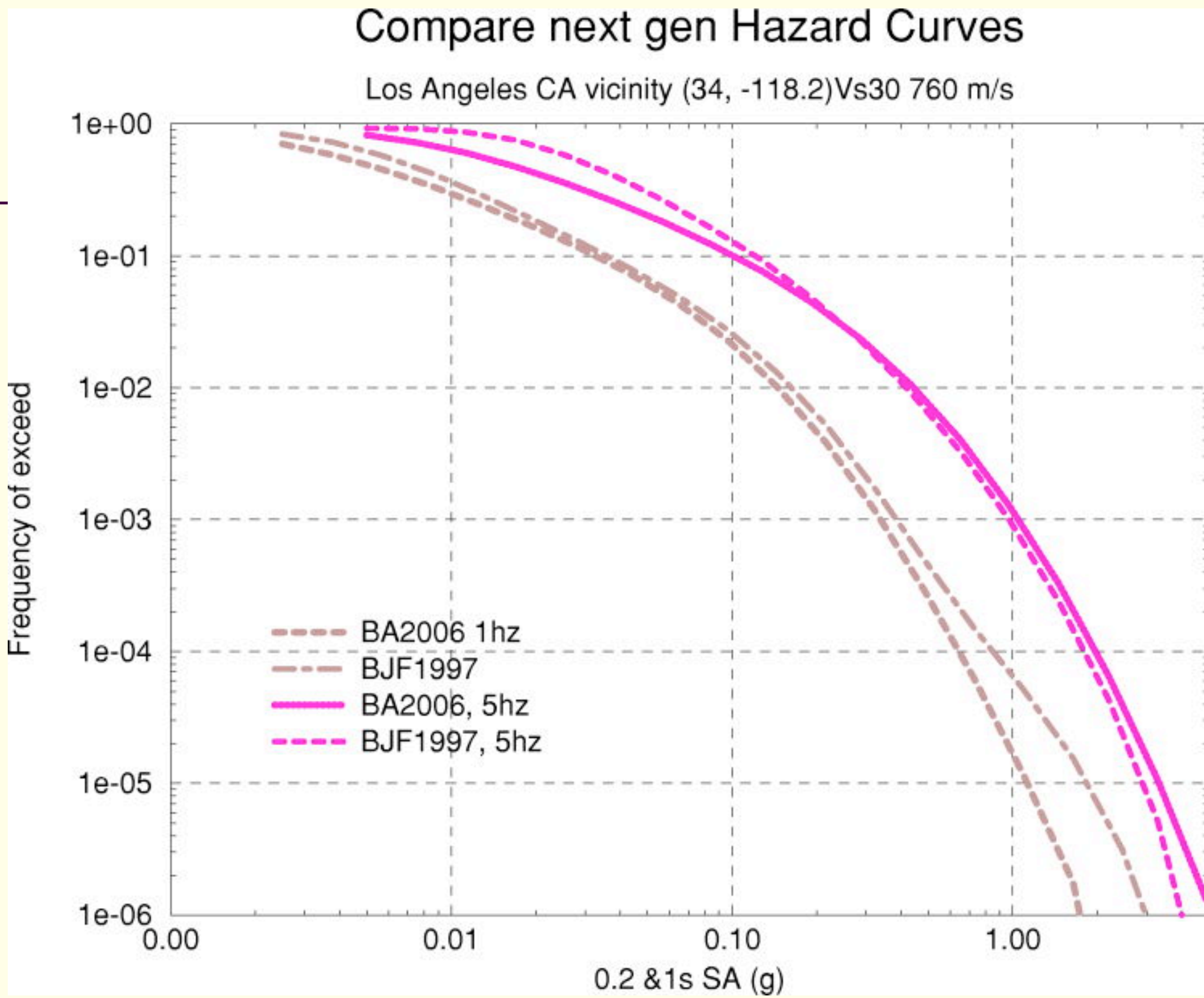
Los Angeles

- Range comparable at 1 hz.
- Less range in NGA models at 5hz.






Compare next gen Hazard Curves
Los Angeles CA vicinity (34, -118.2)Vs30 760 m/s
Frequency of exceed
1e+00
1e-01
1e-02
1e-03
1e-04
1e-05
1e-06
0.00
0.01
0.10
1.00
0.2 &1s SA (g)
AS05 1hz
AS97
AS05, 5hz
AS97, 5hz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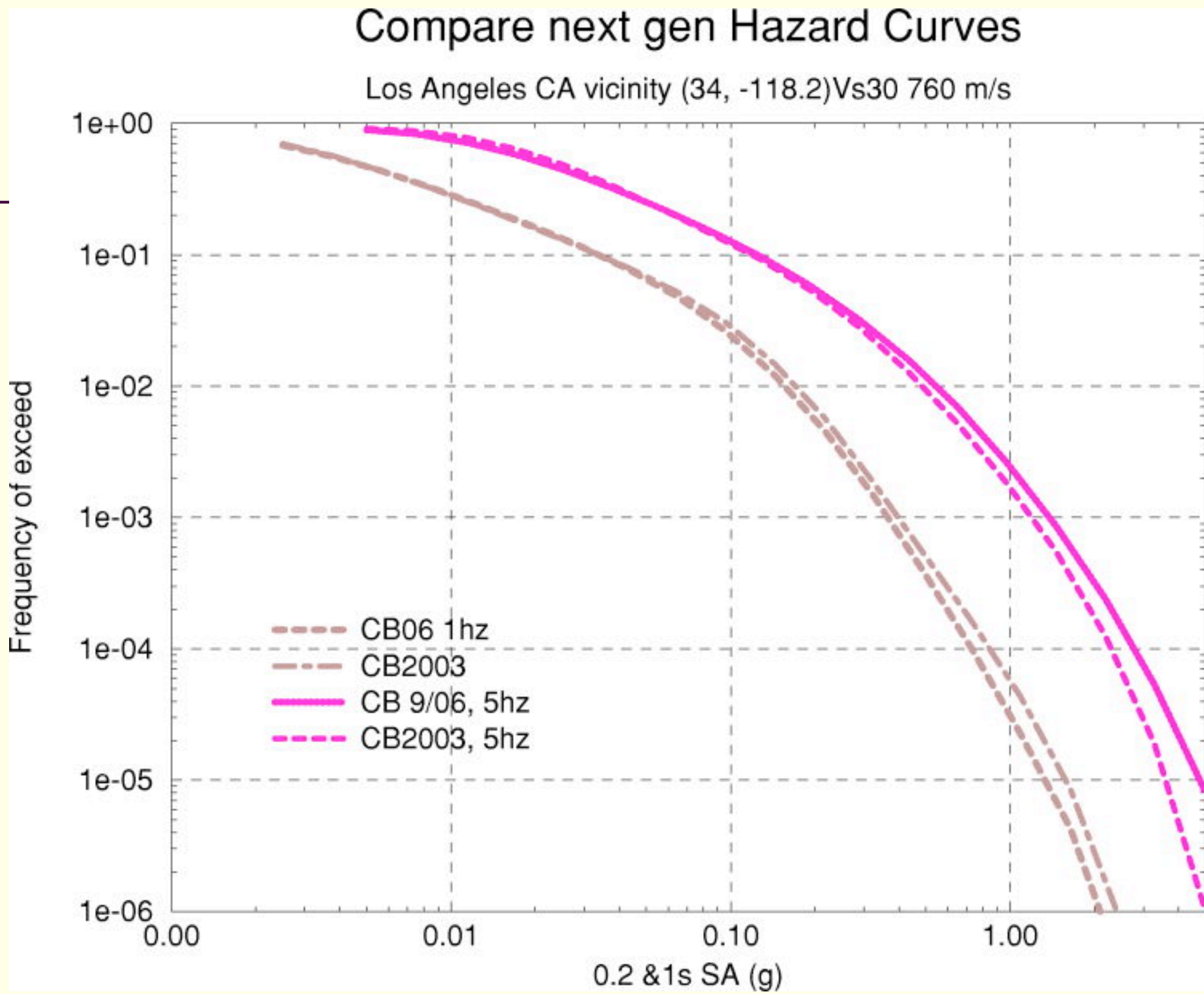
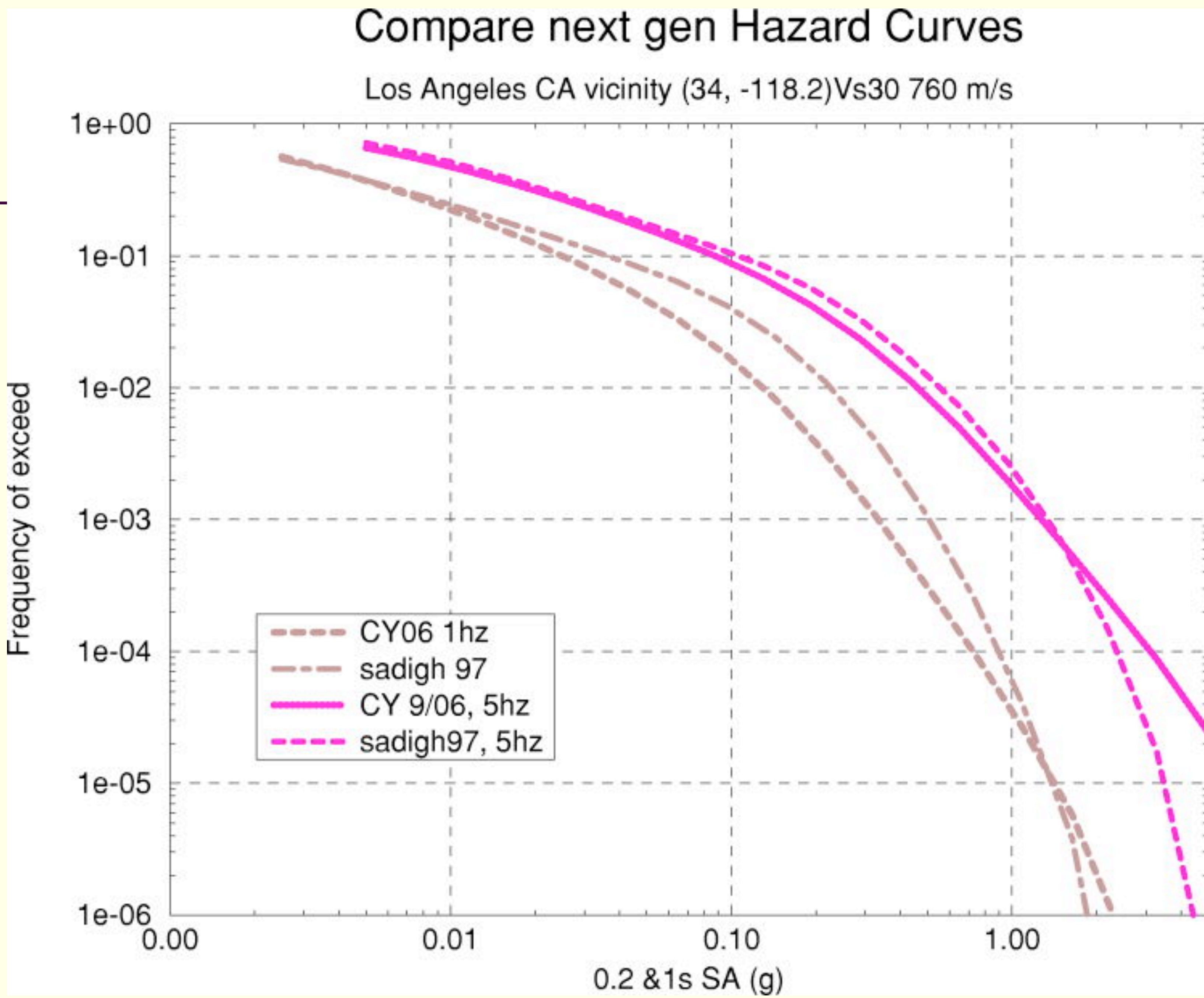
1e-02
1e-03
1e-04
1e-05
1e-06
0.00
0.01
0.10
1.00
0.2 &1s SA (g)
BA2006 1hz
BJF1997
BA2006, 5hz
BJF1997, 5hz


Compare next gen Hazard Curves
Los Angeles CA vicinity (34, -118.2)Vs30 760 m/s
Frequency of exceed
1e+00
1e-01
1e-02
1e-03
1e-04
1e-05
1e-06
0.00
0.01
0.10
1.00
0.2 &1s SA (g)
CB06 1hz
CB2003
CB 9/06, 5hz
CB2003, 5hz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1e+00
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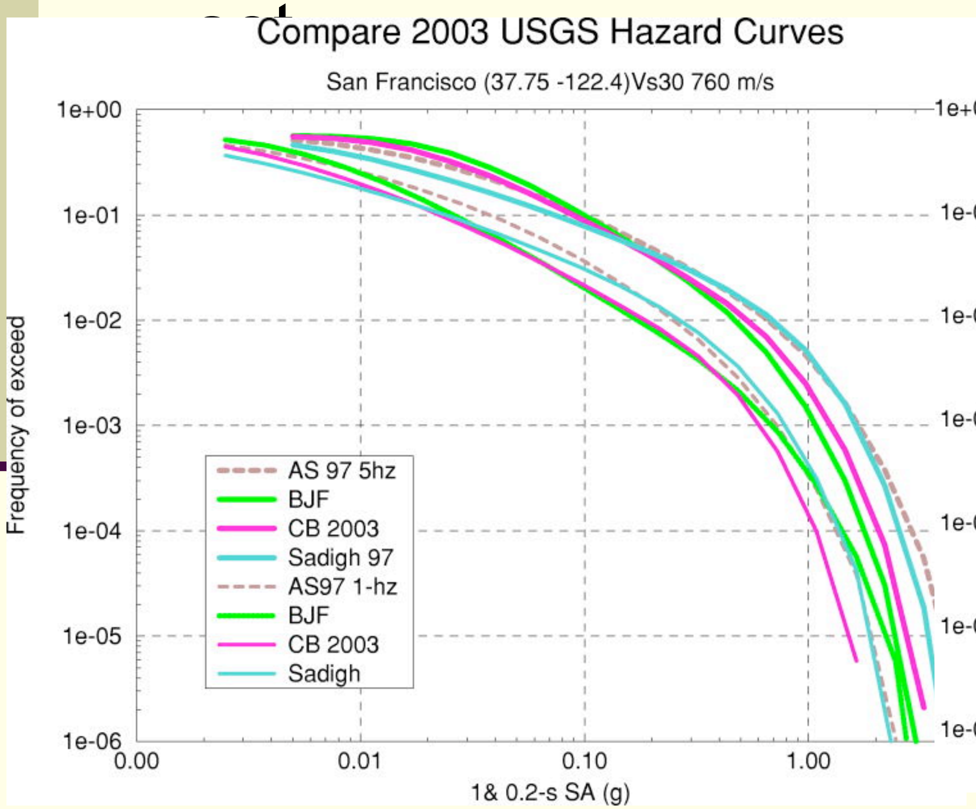
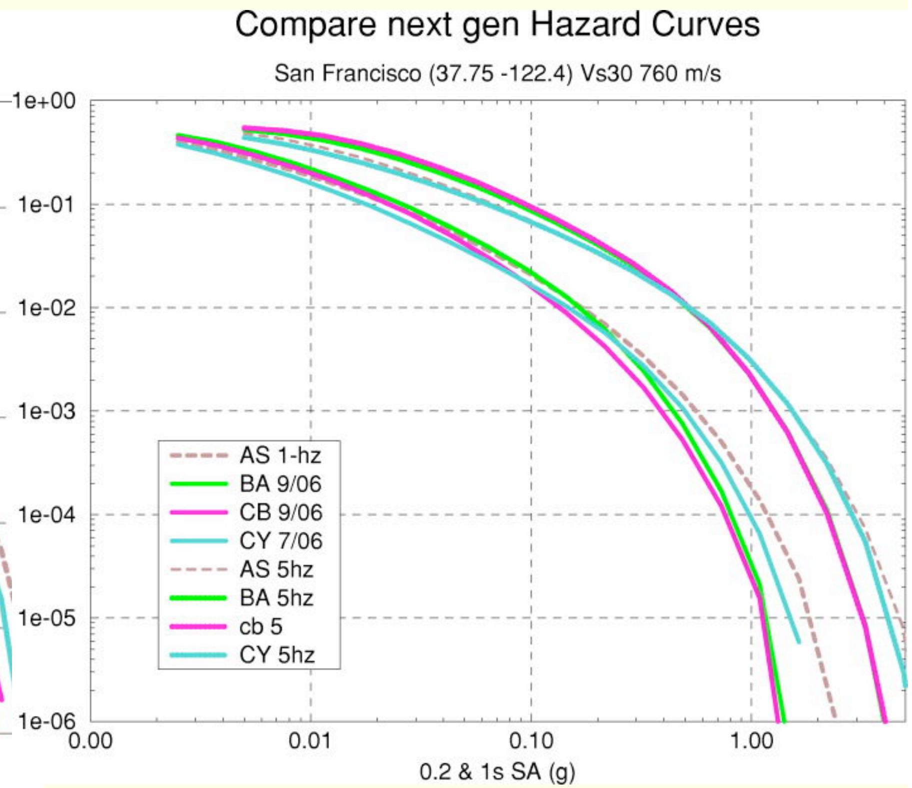
1e-03
1e-04
1e-05
1e-06
0.00
0.01
0.10
1.00
0.2 &1s SA (g)
CY06 1hz
sadigh 97
CY 9/06, 5hz
sadigh97, 5hz

San Francisco

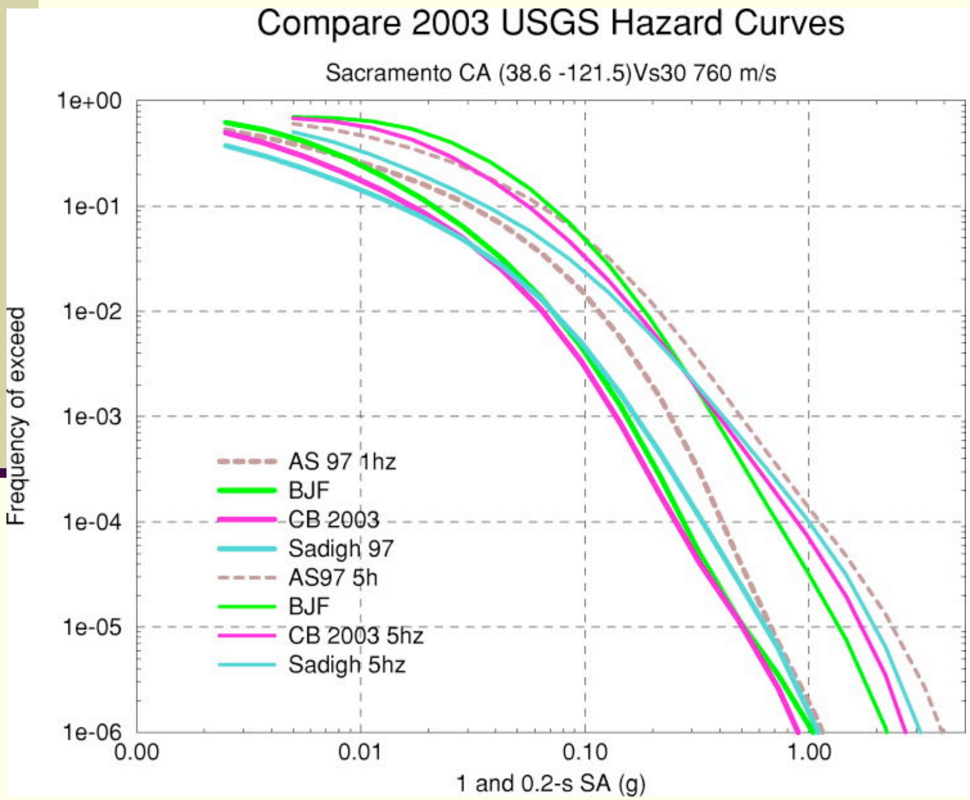
- Comparable at 1 hz
- NGA exhibits less range at 5 hz than previous

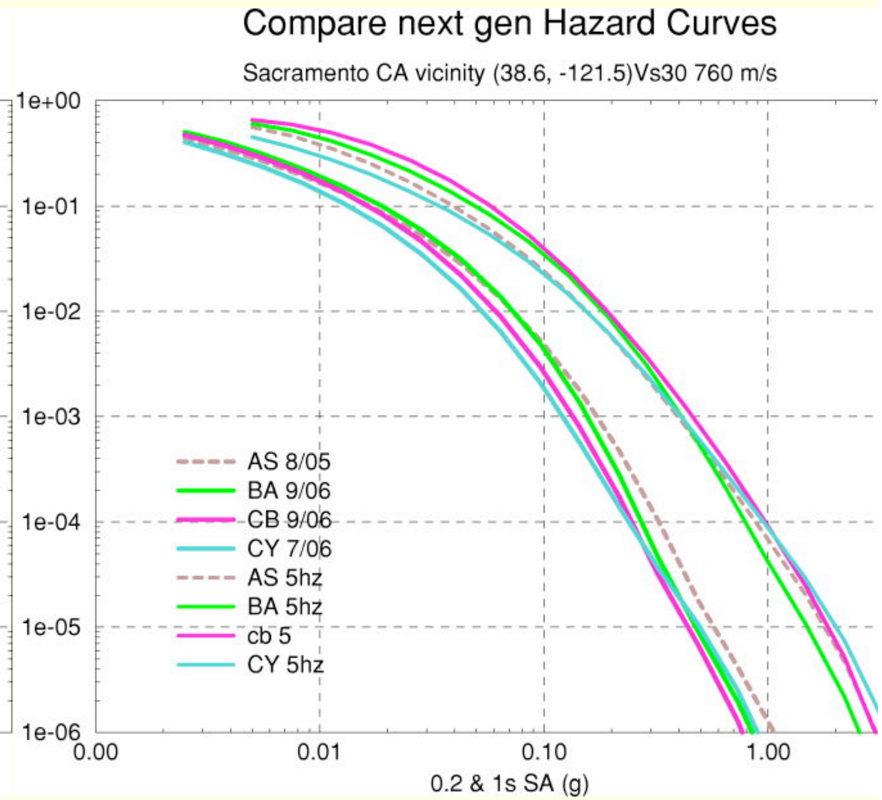




Sacramento

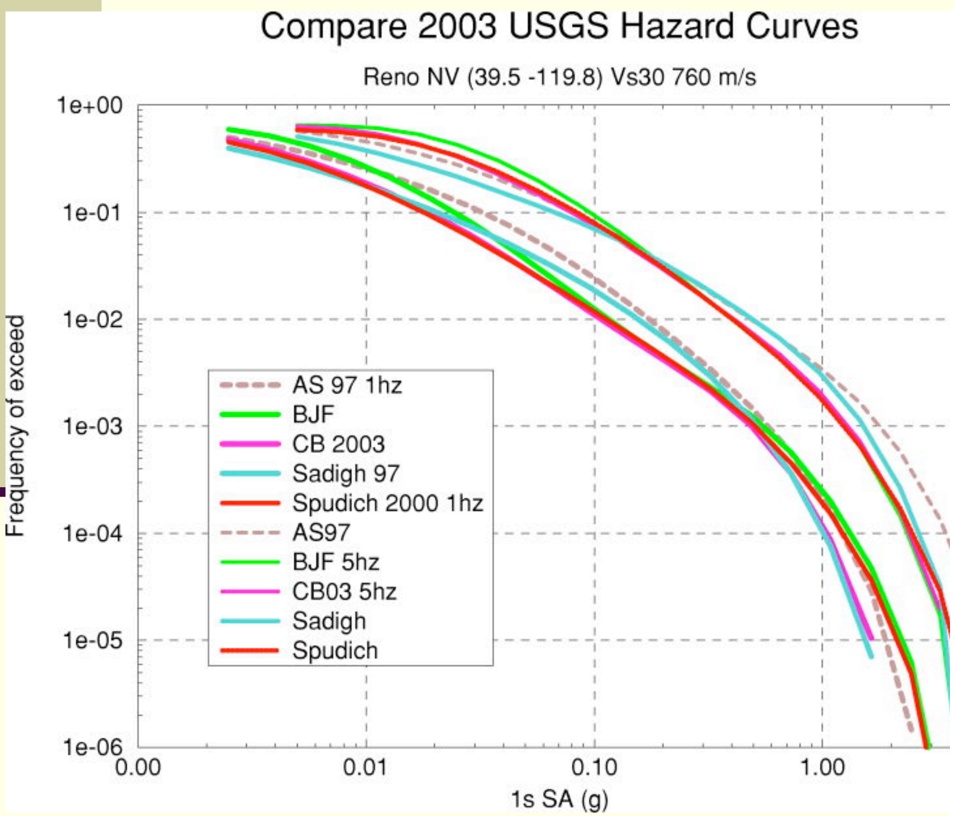
- Except for A&S 1997, comparable range
- A&S (2005) exhibit closer agreement w/NGA.

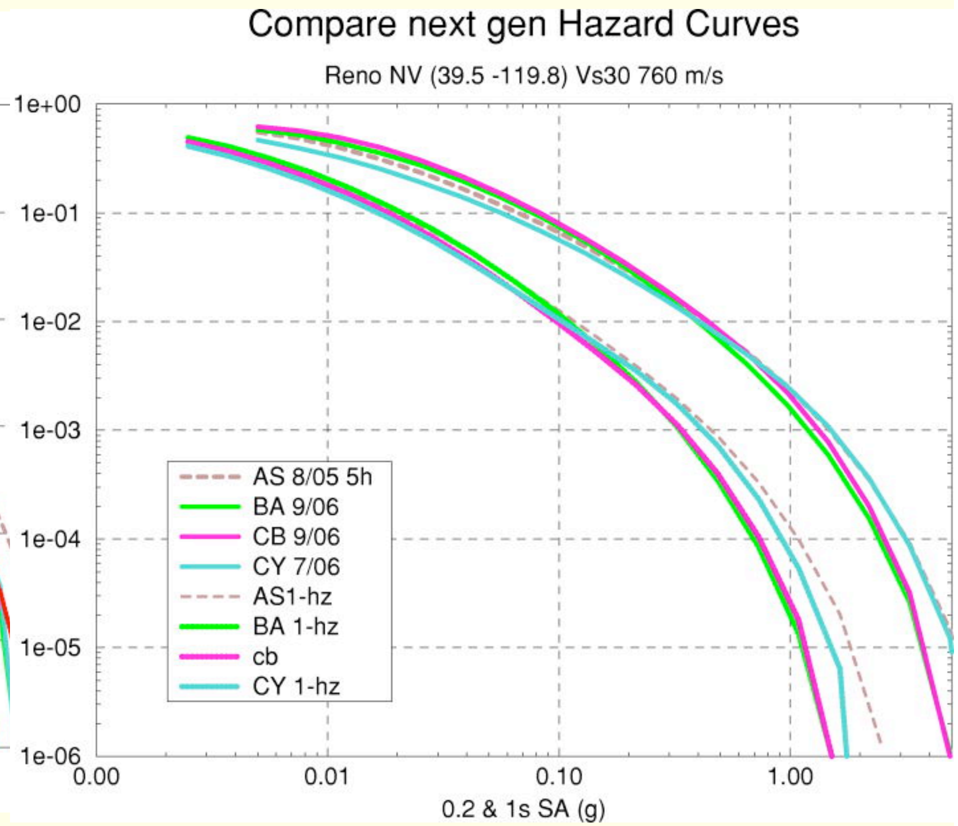




Reno

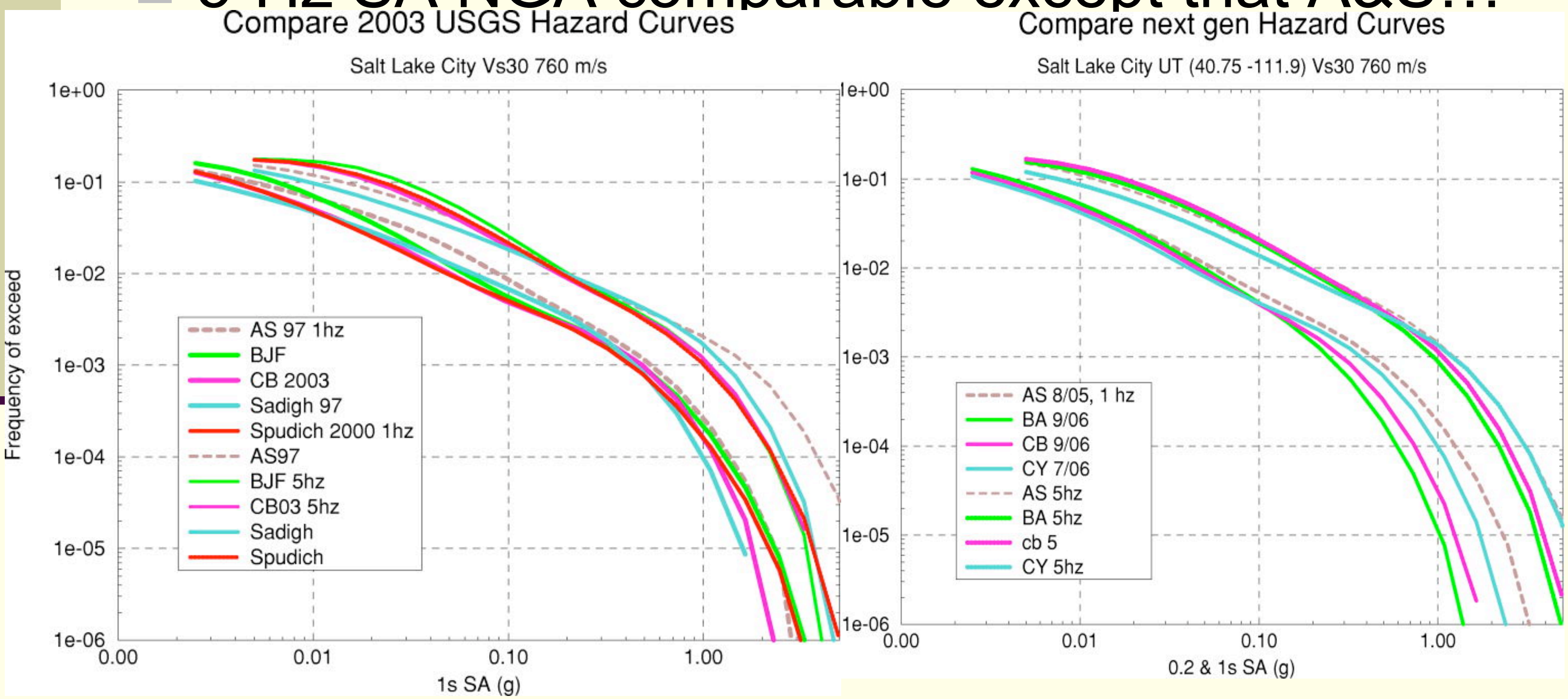
- Comparable range of NGA curves as previous (which now includes Spudich et al)





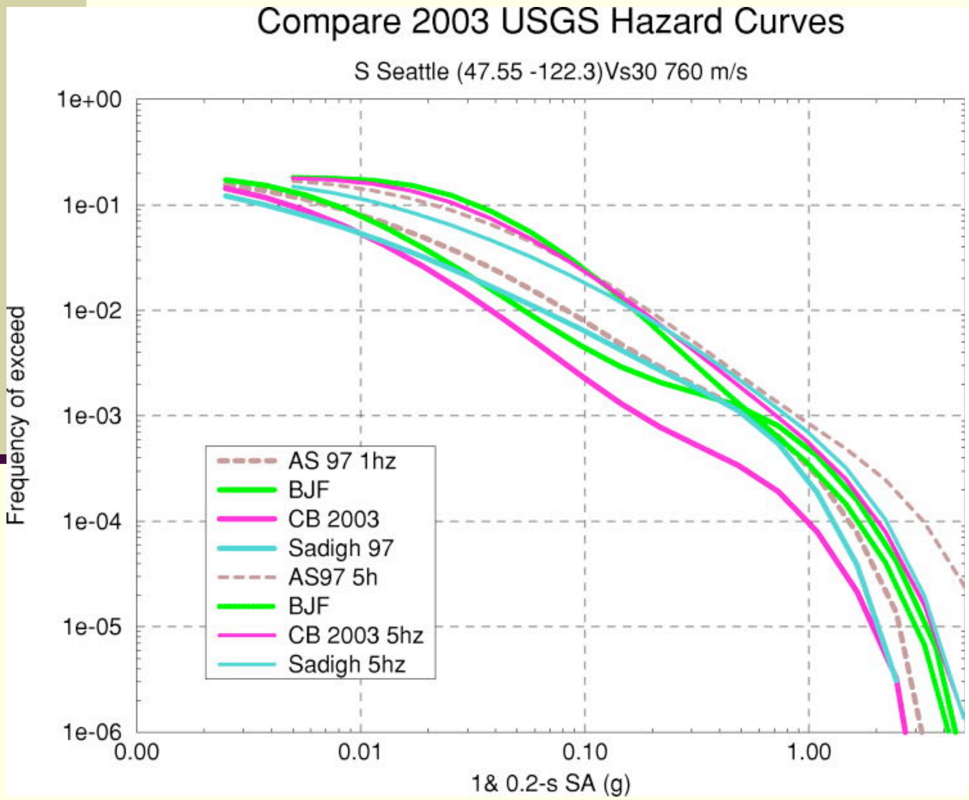
Salt Lake City

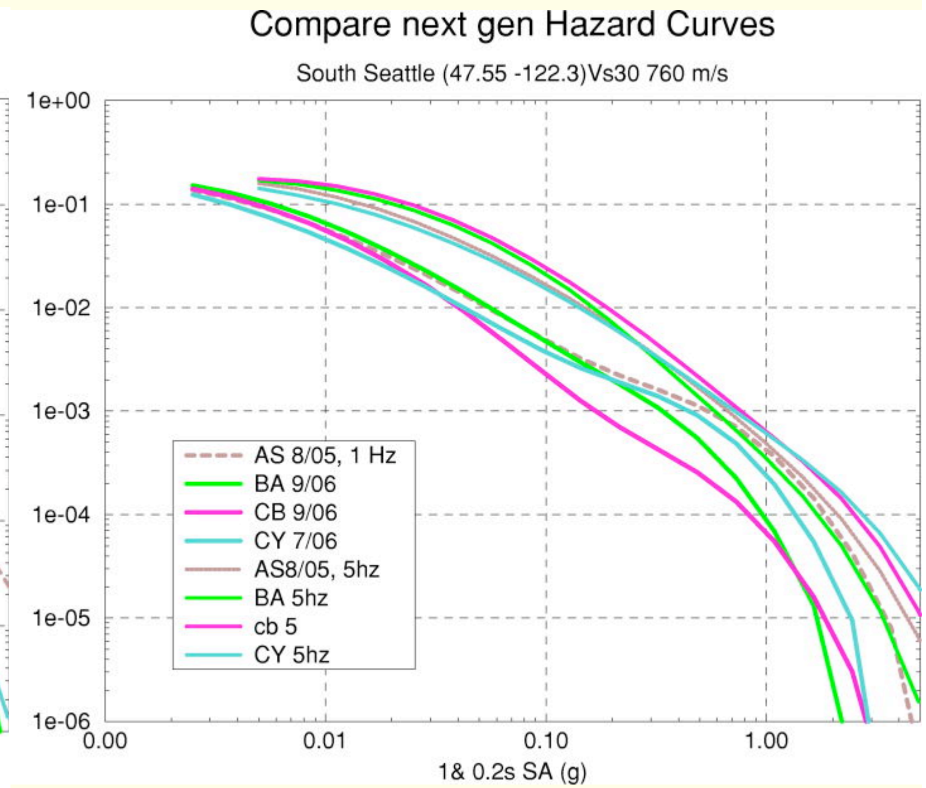
- 1-Hz SA NGA greater range than previous
- 5-Hz SA NGA comparable except that A&S…



South Seattle

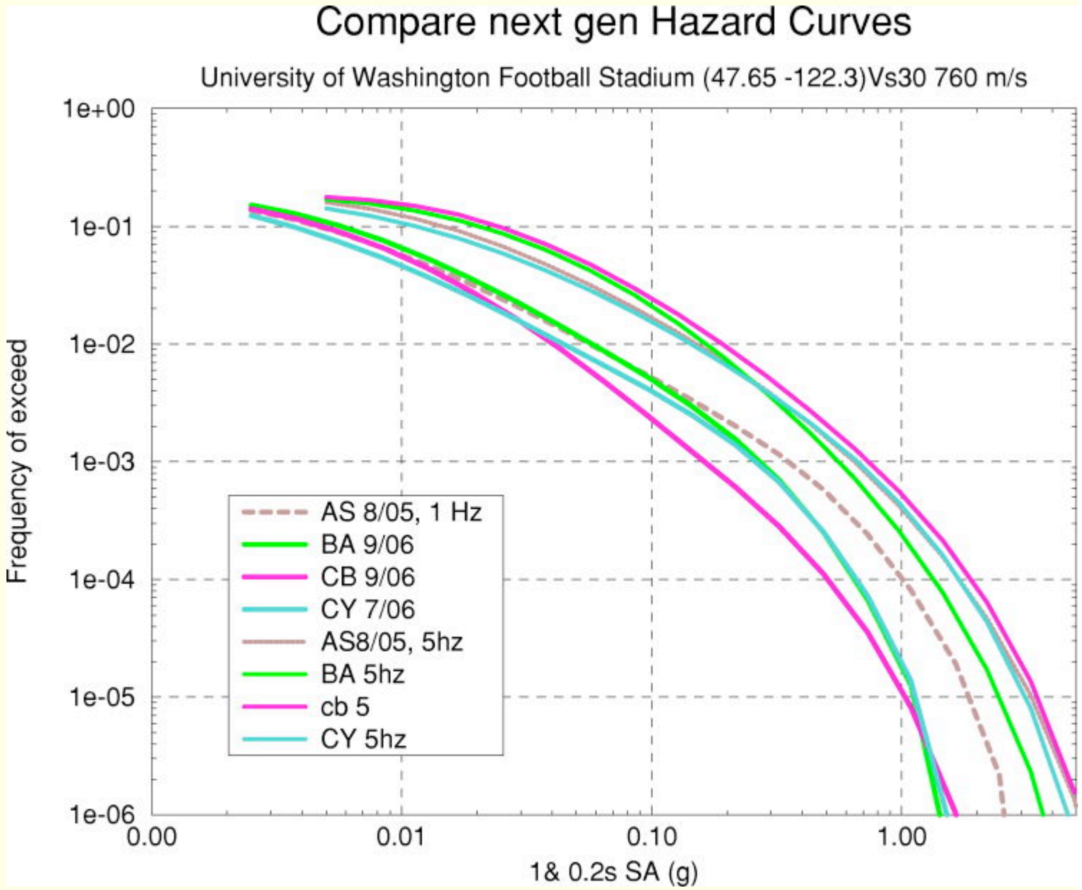
- Site on hanging wall of Seattle fault (thrust)
- Comparable range in NGA compared to prev.





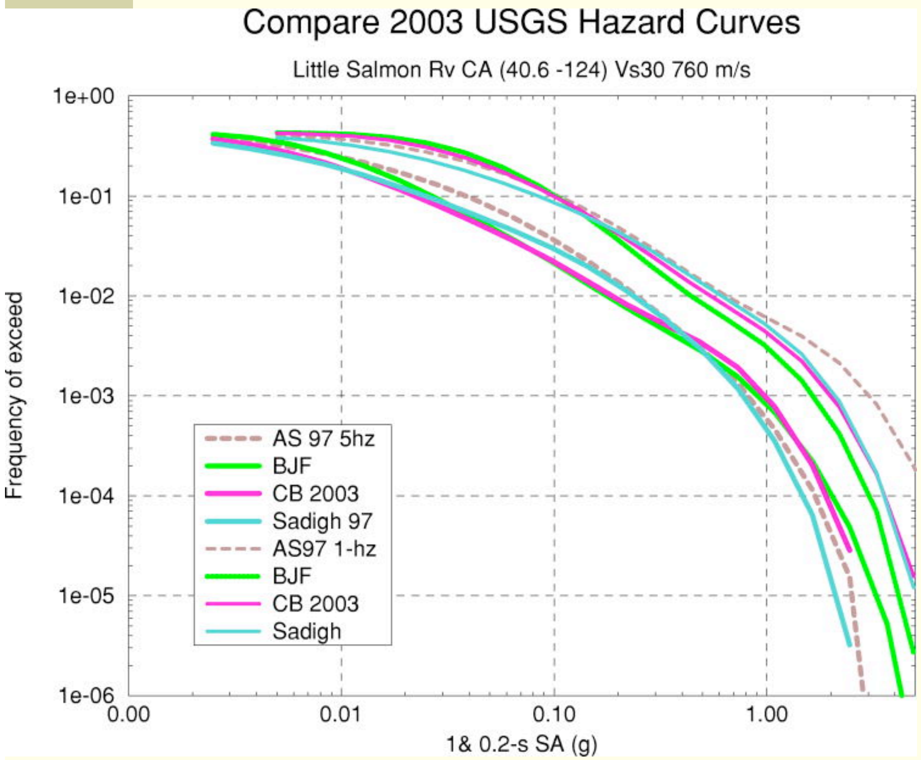
University of Washington, footwall

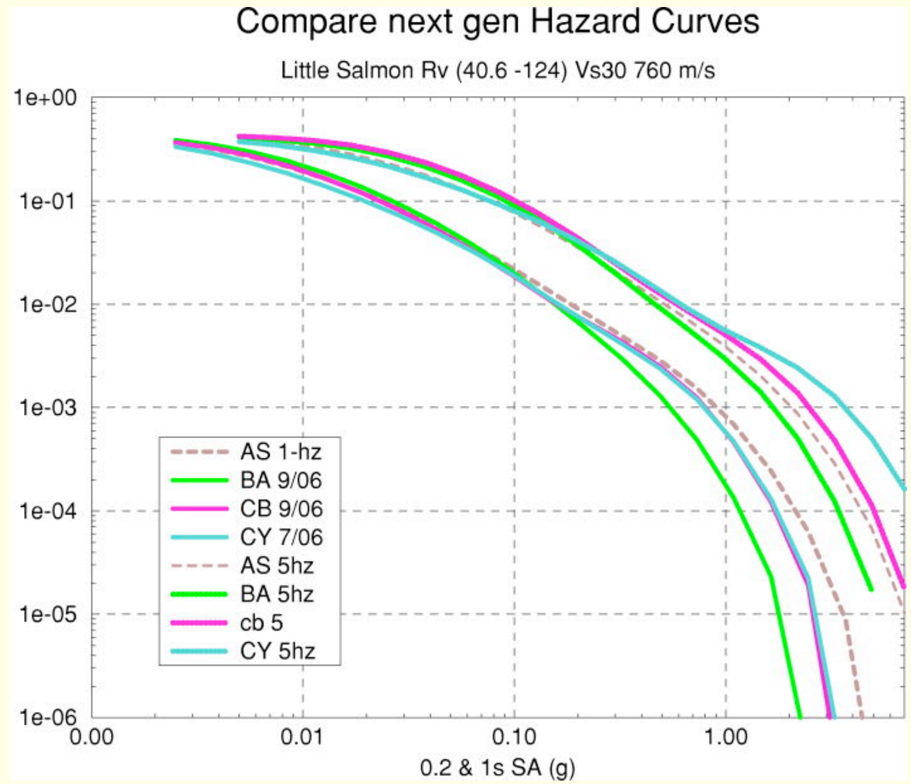
- Comparable range of curves.



Little Salmon fault (N CA coast)

- Increase in variability of NGA vs. previous
- Site on hanging wall of thrust fault. BA est. ↘





Conclusions on Epistemic Uncert.

- Comparison of hazard curves associated with past and current models does not provide compelling evidence that there has been a significant reduction in variability due to any perceived “convergence” of NGA models.
- This tentative conclusion is of course subject to revision based on more comprehensive examination than that shown.

Rock and Soil

- Different because of local conditions. Vs30 term tries to capture these differences.
- Different because of basin response. NGA worked on but some (CB) claimed zero or less than zero basin hazard in many cases.
- Different because of topographic response. Rock instruments typically sited on ridges, edges of terraces, near hill tops, and so on. Soil instruments usually at sites in flat alluvial valleys.

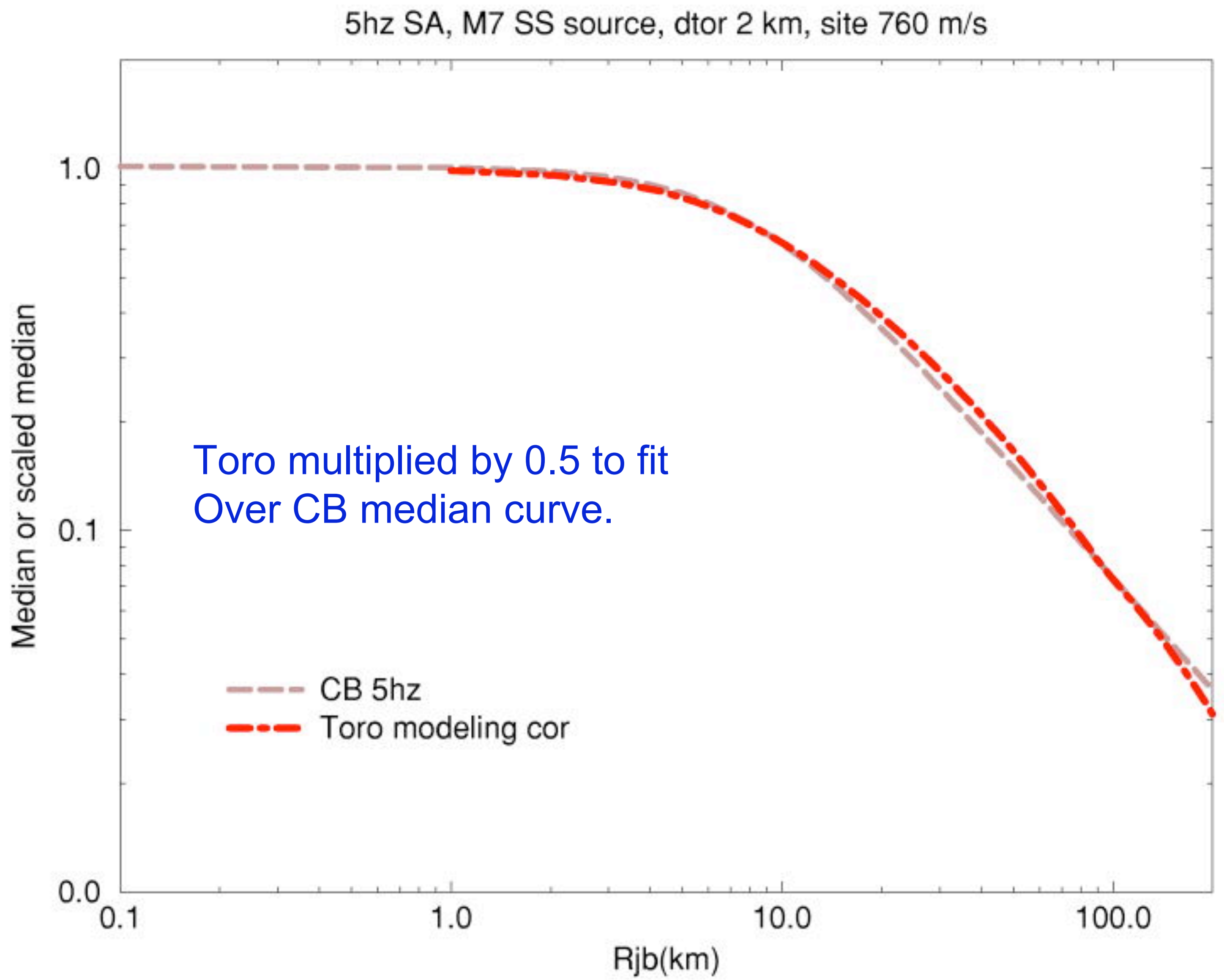
Why might rock response not represent basement response?

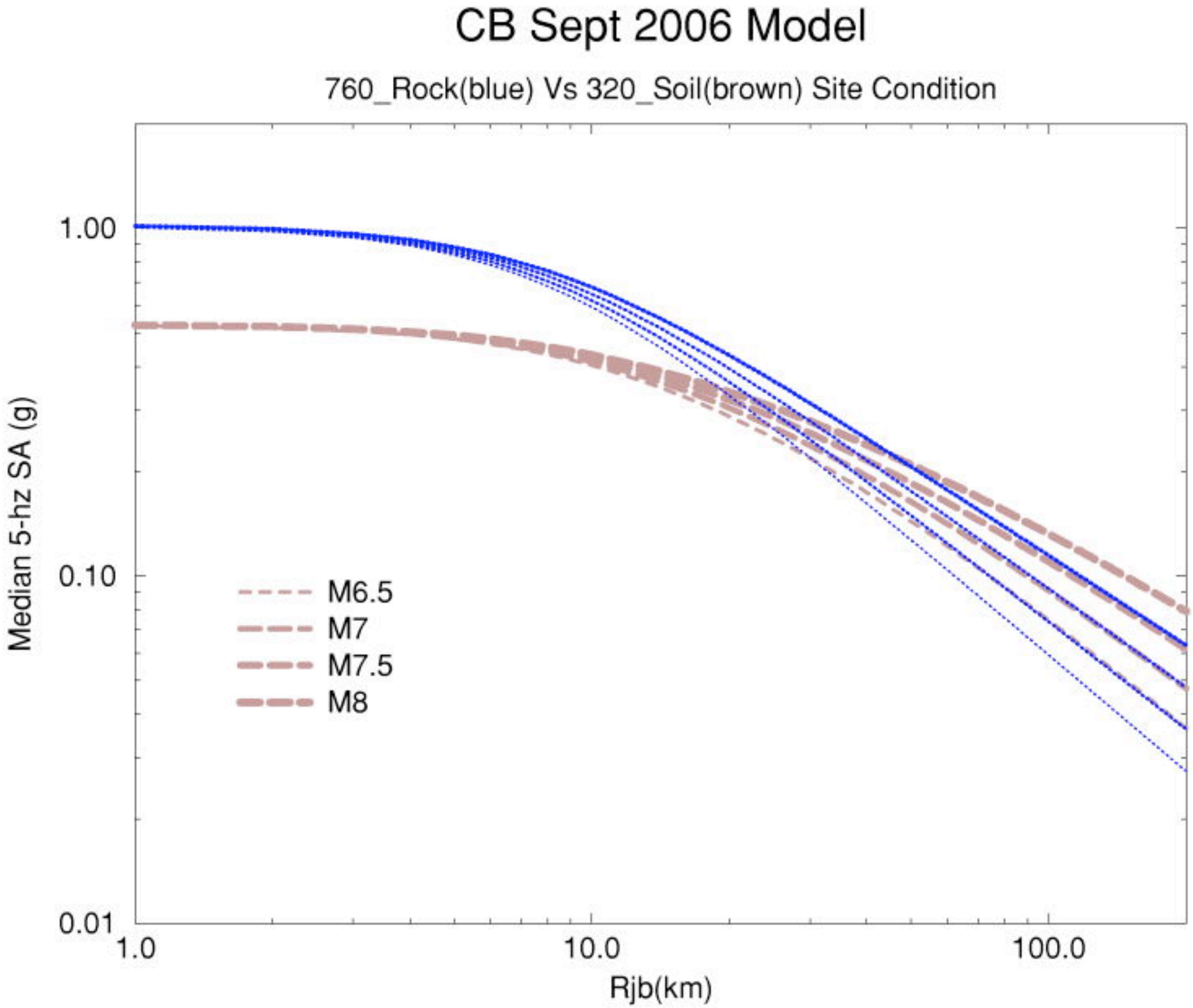
- Most rock SM stations are deployed at high locations, few at topographic lows. Basement response will not be recorded on mountain/hill/ridge top.
- LA region: ORR (ridge), MTW (mountain), GPK (hill), PACD abutment (mountain), LF6 (ridge), Sandberg Bald Mtn. (mountain top next to canyon). Better: PAS.
- SF Bay region: CLI (cliff), Telegraph Hill (ridge), Pacific Heights & Diamond Heights (ridges), Crystal Springs Reservoir (ridge), CSUH (terrace on hillside)
- NGA modelers don’t mention topographic amplification.
- CB conclusion of null basin response could be biased by factors such as topographic amplification in rock sample.

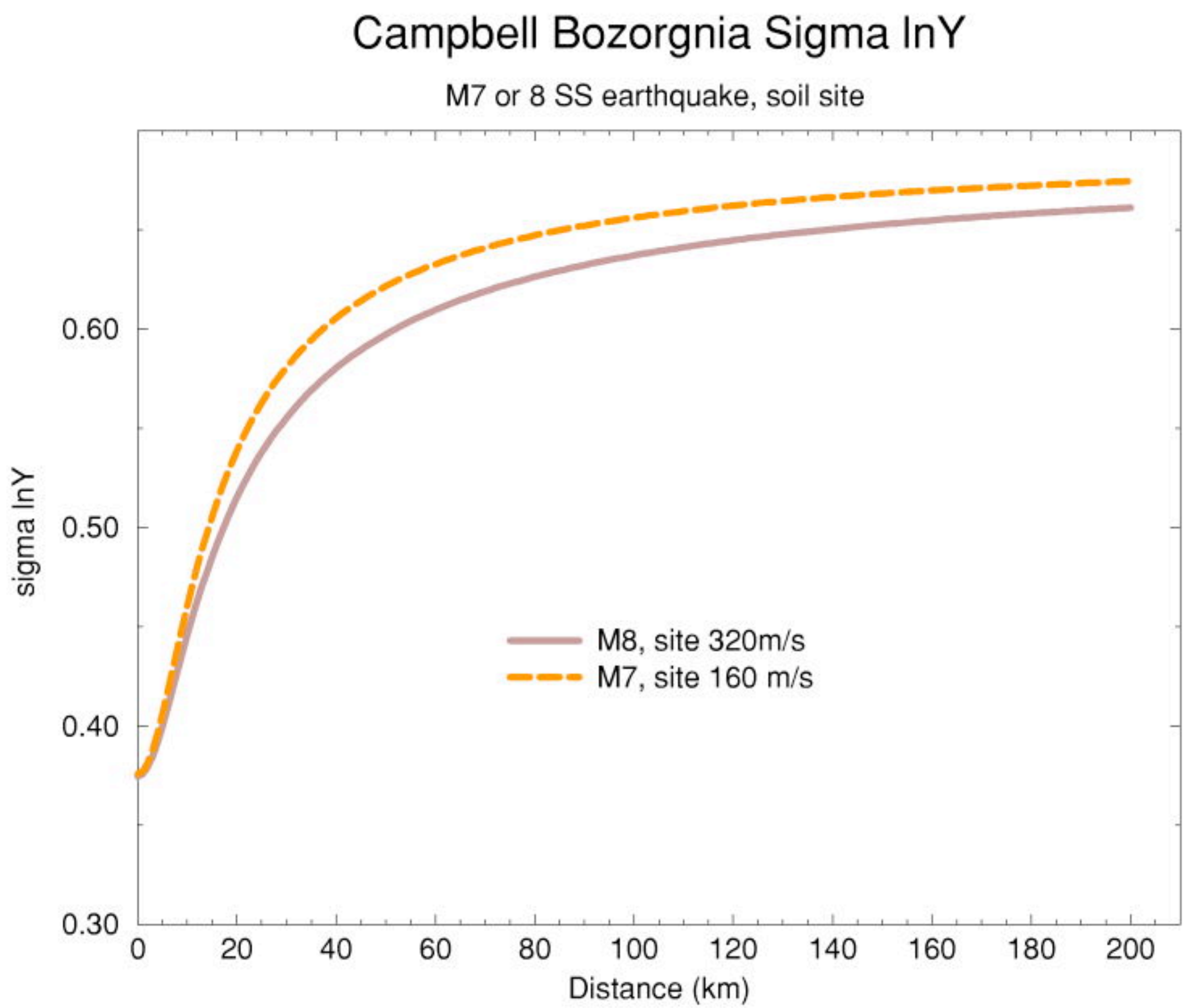
Returning to the NGA models…

- Soil-site median curves are lower than rock-site curves for corresponding sources when the sources are up to 30 km away.
- Soil-site median curves decay far less rapidly than rock-site curves due to decreasing nonlinear soil siteamp (i.e., increasing linear siteamp) with distance.
- Additionally (CB06), σ for soil reduced near-src
- Conclusion: Soil-site deagg of hazard will give significantly different mean and modal sources than rock-site. We should not use rock modal M as a proxy for soil modal M in engineering apps.

5hz SA, Compare Camp-Bozorgnia 6/06 with Toro




CB Sept 2006 Model
760_Rock(blue) Vs 320_Soil(brown) Site Condition
Median 5-hz SA (g)
1.00
0.10
0.01
1.0
10.0
100.0
Rjb(km)
M6.5
M7
M7.5
M8


Campbell Bozorgnia Sigma lnY
M7 or 8 SS earthquake, soil site
sigma lnY
0.30
0.40
0.50
0.60
0
20
40
60
80
100
120
140
160
180
200
Distance (km)
M8, site 320m/s
M7, site 160 m/s

Conclusion

- SAF and other short recurrence-time large sources take on new significance when performing PSHA at soil sites in urban areas, no matter how far the site is from those sources at least out to the NGA agreed upon Rmax=200 km (500 – 1000 km?).

Compare 2% in 50 year PSHA maps

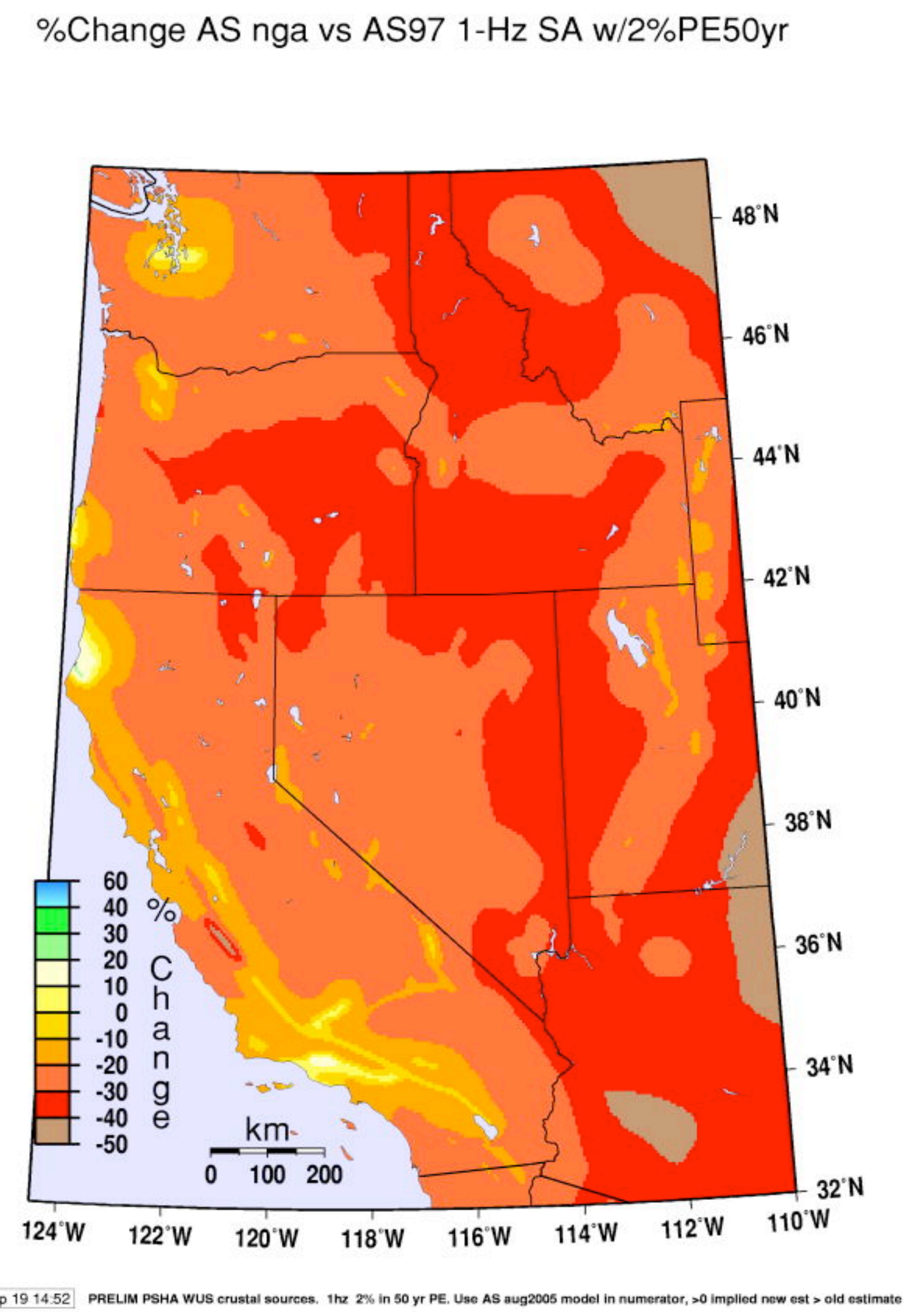
- Use same WUS crustal source models and compare parent-child attenuation only
- Omit other sources: subduction, Benioff, CEUS sources that affect WUS sites
- For this study, use same top-of-rupture as that used in 2003 USGS PSHA. Most faults have top of rupture at 0 km; many blind thrusts have 5 km or so top. C-faults (fault location unknown) have uniform 5 km top-of-rupture.
- New fault parameters are present in these models especially for Basin&Range faults (e.g. 50º dip).

Order of presentation

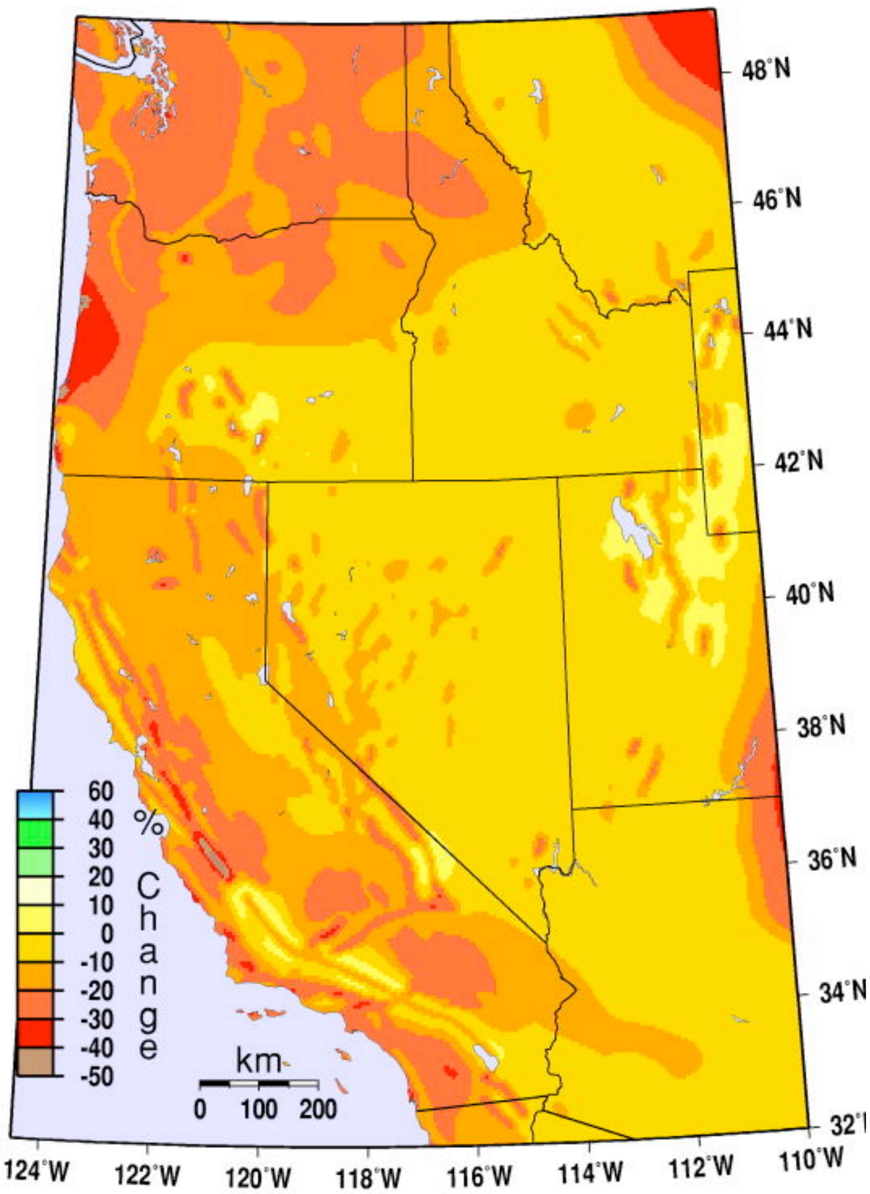
- AS (8/05) compared to AS 1997
- BA 9/06 compared to BJF, 1997
- CB 9/06 compared to CB2003
- CY 9/06 compared to Sadigh et al., 1997
- Combined NGA compared to combined earlier set

1-s SA

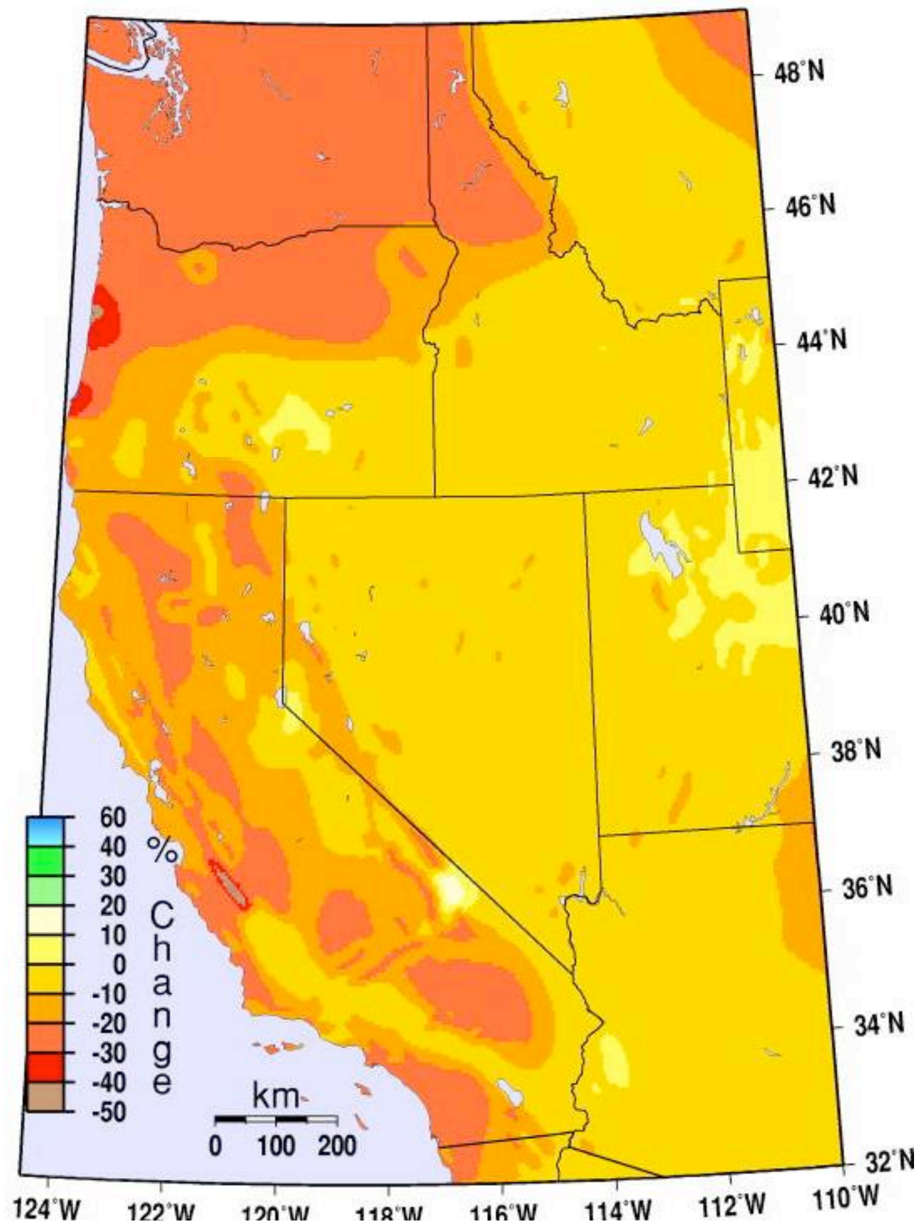
- 760 m/s Vs30 should be reduced
- B&R SA reduction 20 to 30%
- W Ca SA reductior order of 10%
- Over faults less reduction of 1s SA



%Change AS nga vs AS97 5-hz SA w/2%PE50yr



%Change AS05 vs AS97 PGA w/2%PE50yr. Vs30=760

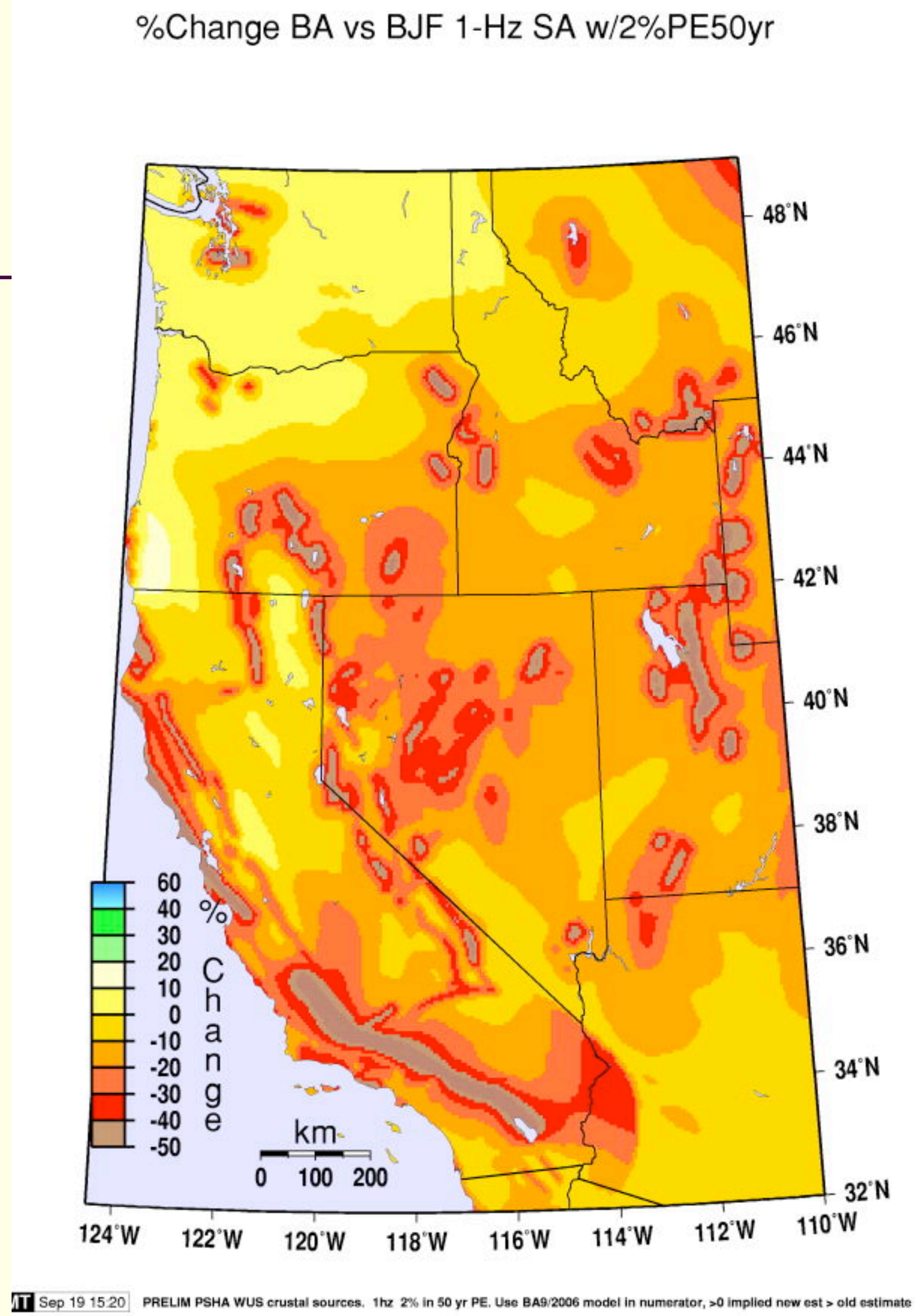


1s, B&A

- 40% reduction over many faults.

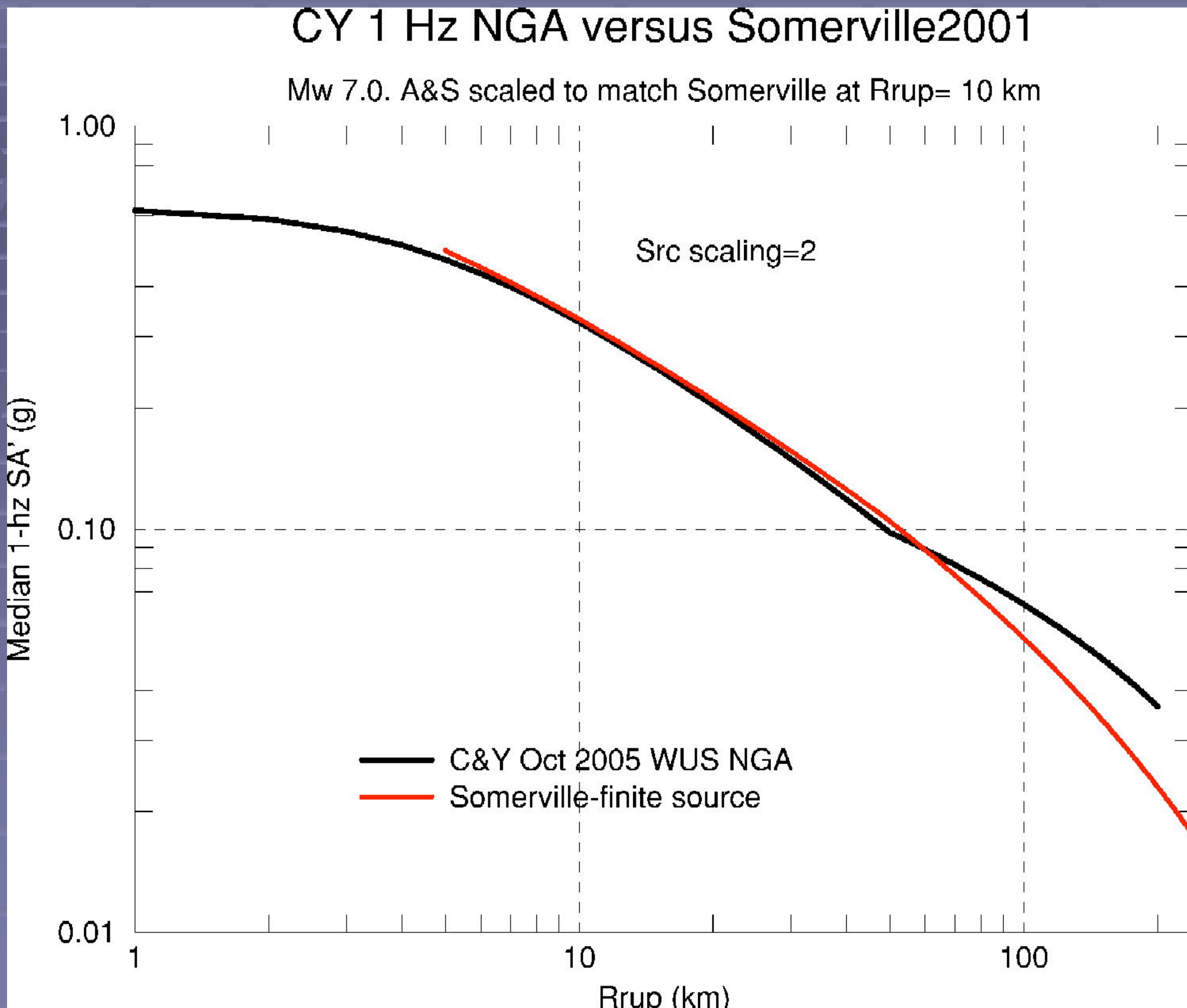
No Vs30 tweeking is justified.

Varying top of rupture has no effect due to Rjb distance metric.

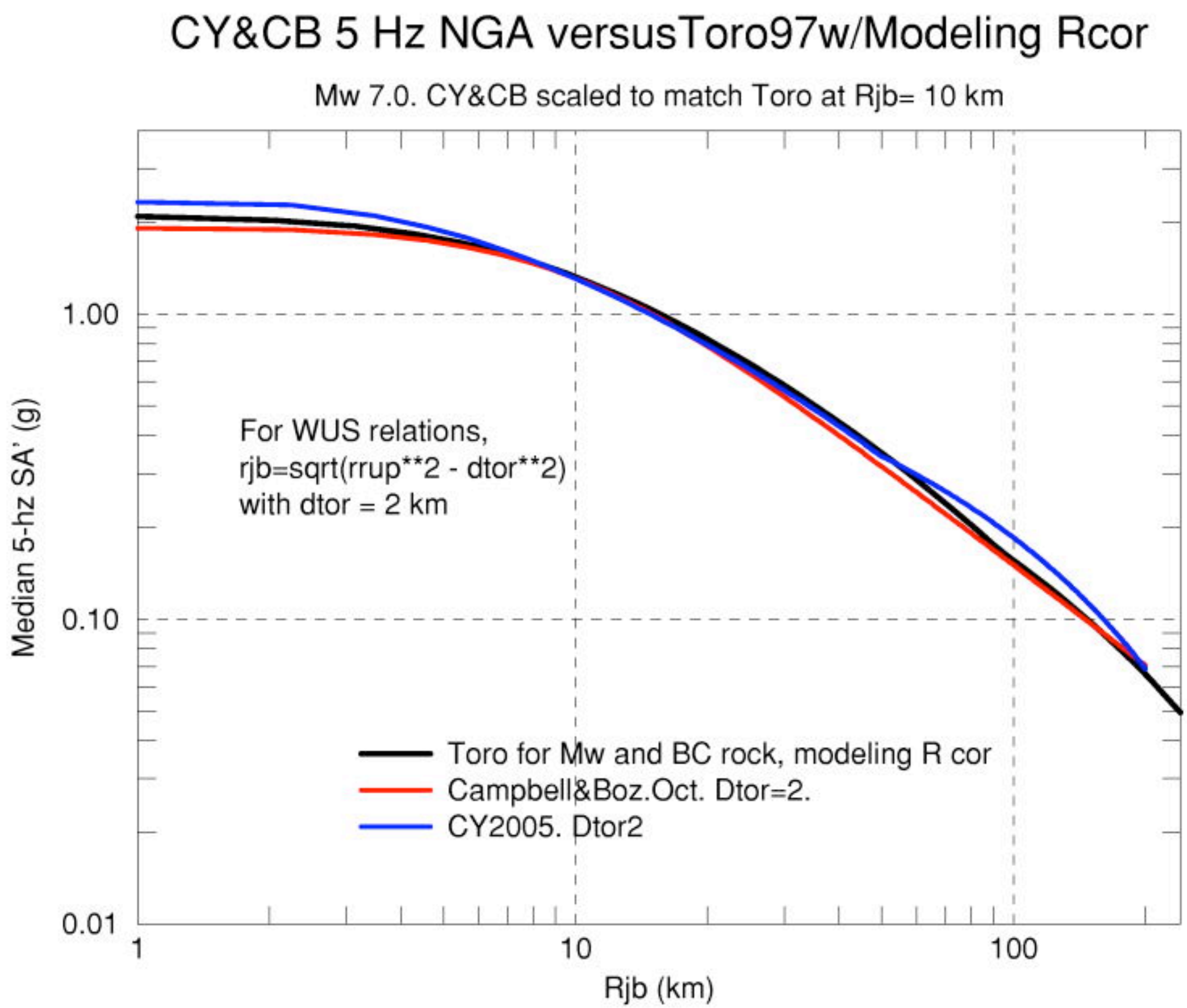


Strong Motion Data Reveal Little about Regional Geology

- NGA regressions based on strong motion data yield same decay rate in WUS as is predicted by Toro, Somerville and others for CEUS
- It is widely acknowledged that SA decay rate in stable cratons is less than it is in tectonically active areas.
- Most developer teams are now constraining distance decay with supplemental data (B&A did this all along).



CY 1 Hz NGA versus Somerville2001
Mw 7.0. A&S scaled to match Somerville at Rrup= 10 km
Src scaling=2
Median 1-hz SA' (g)
1.00
0.10
0.01
1
10
100
Rrup (km)
C&Y Oct 2005 WUS NGA
Somerville-finite source

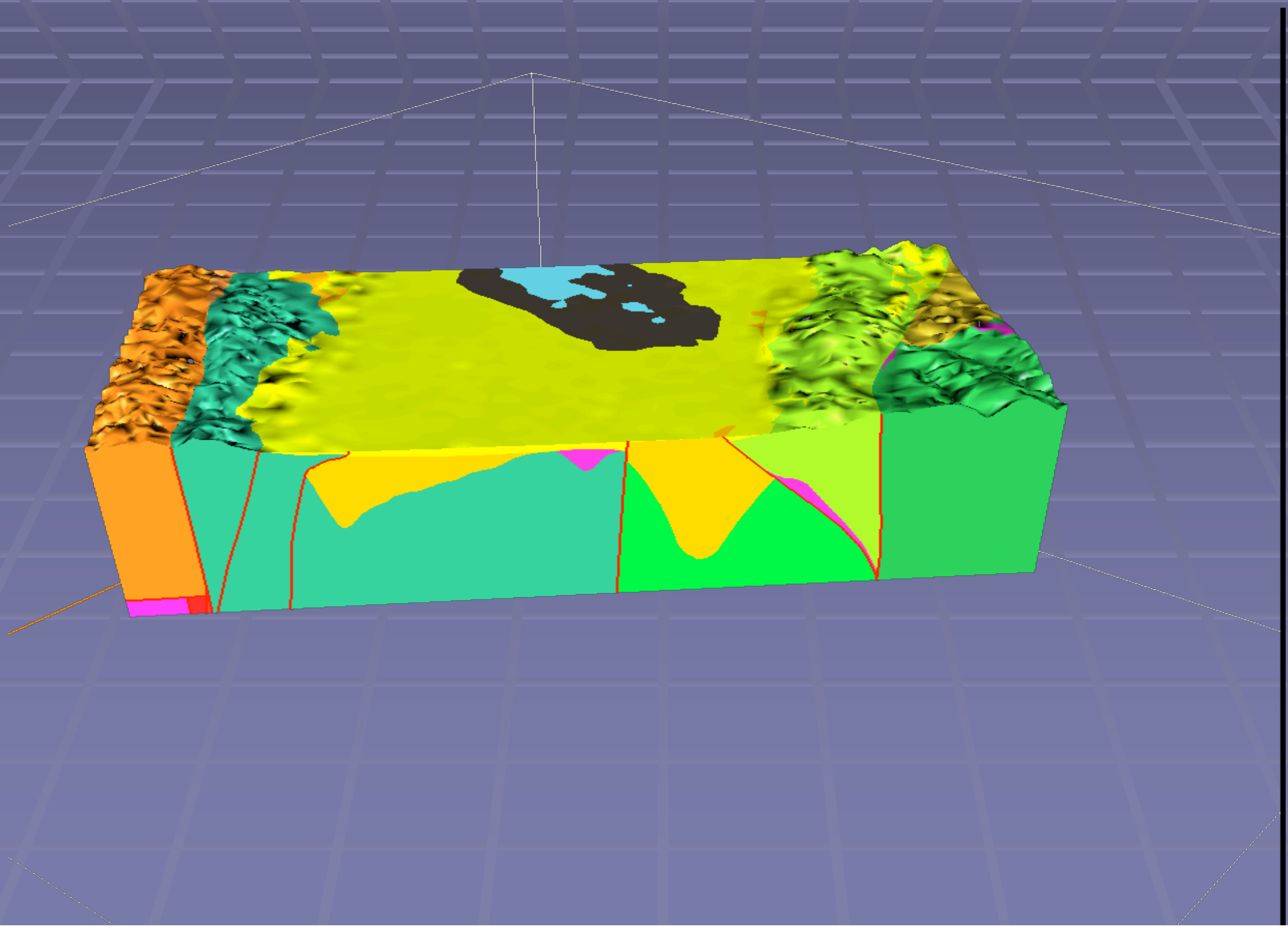


CY&CB 5 Hz NGA versusToro97w/Modeling Rcor
Mw 7.0. CY&CB scaled to match Toro at Rjb= 10 km
Median 5-hz SA' (g)
1.00
0.10
0.01
1
10
100
Rjb (km)
For WUS relations,
rjb=sqrt(rrup**2 - dtor**2)
with dtor = 2 km
Toro for Mw and BC rock, modeling R cor
Campbell&Boz.Oct. Dtor=2.
CY2005. Dtor2

Tent Models

- Physical models should be as simple as possible, but no simpler (A.E.).
- Before NGA, strong motion regression formulas symbolically constructed a symmetric tent around fault.
- Tent model is retained by NGA development teams
- Important Fact: Geology around faults is not symmetric
- Crustal blocks have slipped tens, maybe hundreds of km.
- Some faults occupy multiple strands. Right steps on dextral-slip systems produce sedimentary basins between strands, called “fault-bounded basins.”
- There are many known basins in SF Bay region. San Leandro, Livermore, Evergreen, Cupertino, Merced, and La Honda are six examples.
- Do at least some basins require modeling to capture their strong-motion potential?
- By adopting tent model, is NGA implicitly answering this q. “no” ?

Geology of Santa Clara Valley

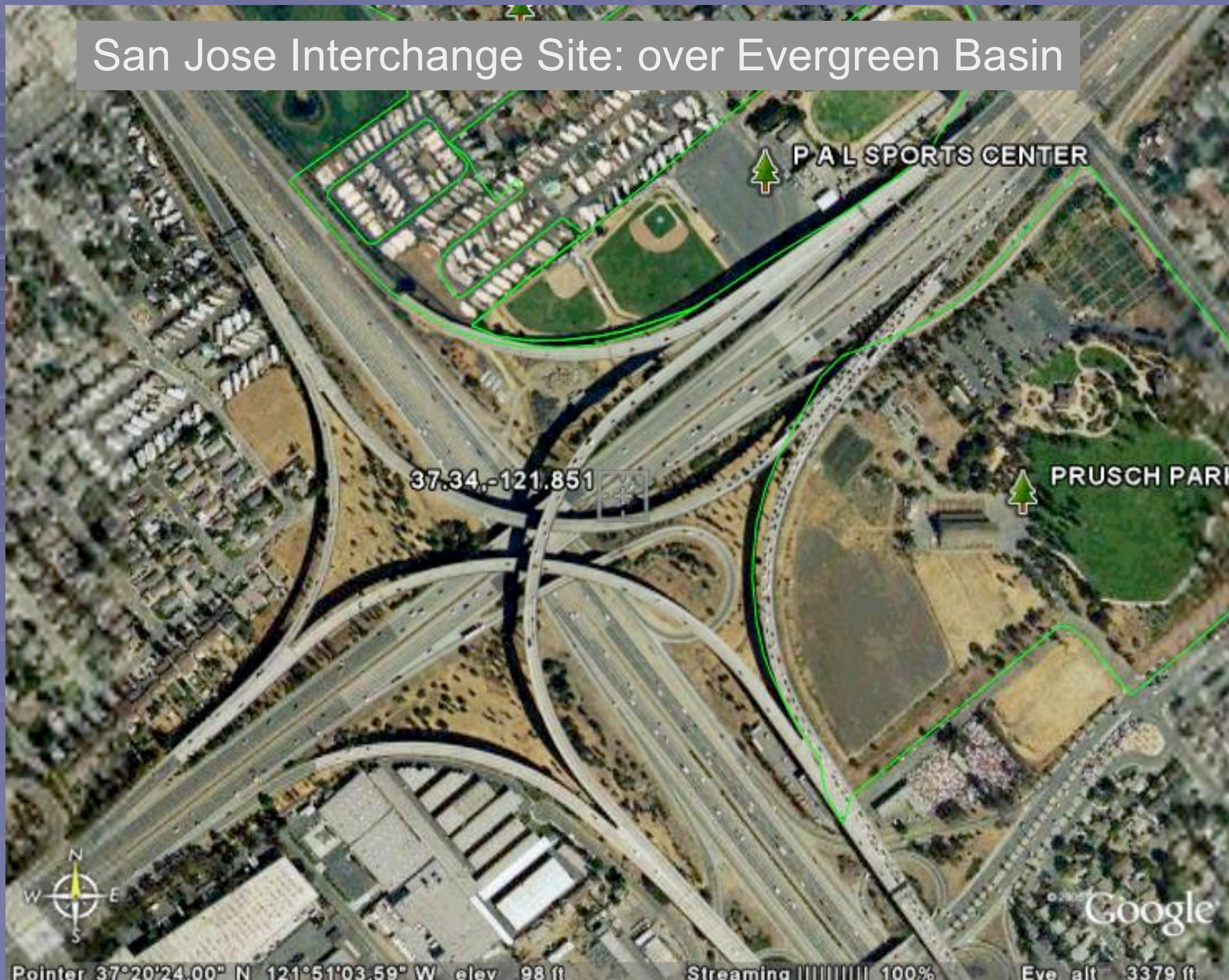


Strong motion data regressions fail to distinguish CEUS from WUS geology

- To what extent do strong motion data distinguish basin response from basement response? Teams don't try to model basin response, but some have individual site terms for depth to Vs2.5. Tent model says symmetry around fault is the norm or working hypothesis. Justification if any is that tradition should not be tampered with without good reason.
- If failure to capture gross regional differences bothers us, why do we not question much more important potential failure to capture basin response? Sub-questions: adequacy of data, adequacy of models.
- Multi story steel frame buildings and other structures with fundamental mode T of 2 to 4 s are routinely built at sites overlying 1-3 km or thicker sedimentary basins.
- Sedimentary basins often have long-period seismic resonances.
- Proper anticipation of basin response is relevant to seismic risk assessment.

Jan 1995 Kobe (H-N) Source

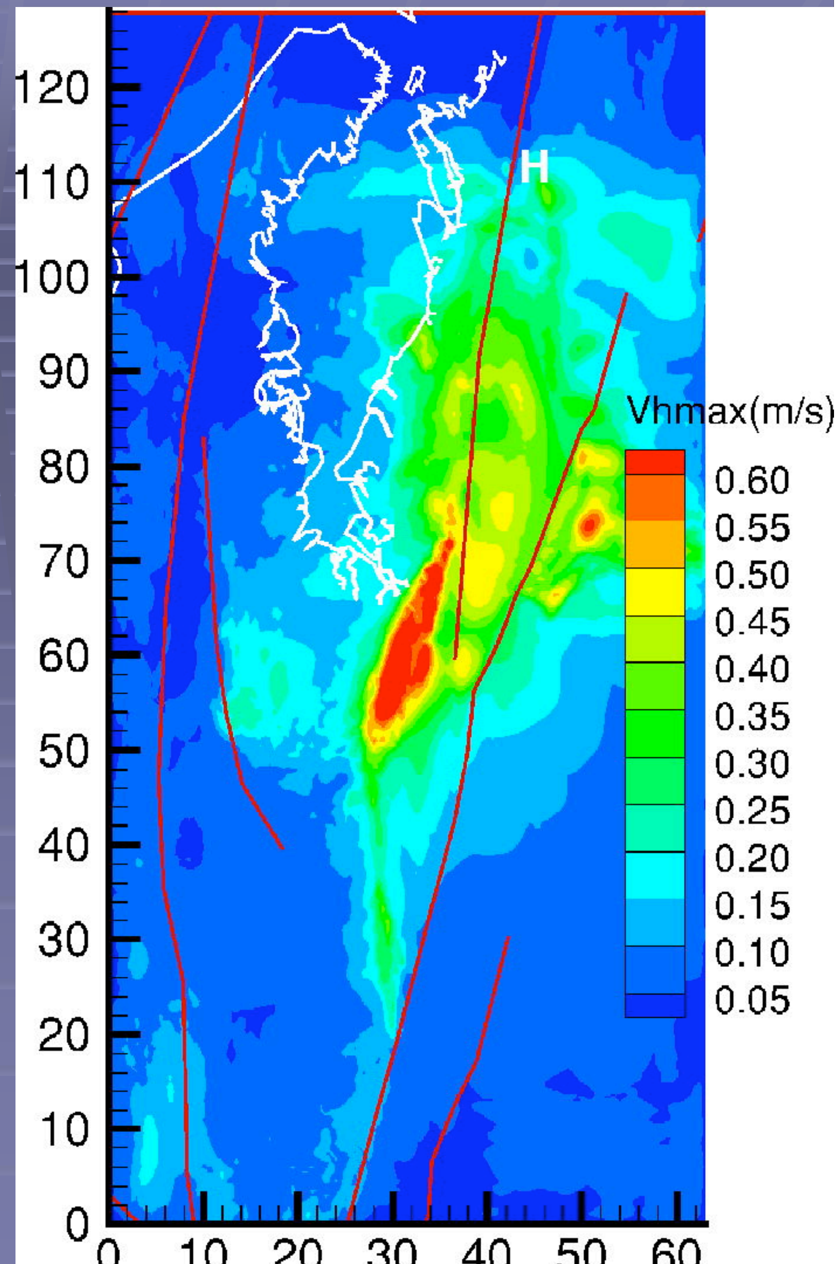
- Destroyed over 100,000 buildings in the sedimentary basin between coastline and Rokko mountains. 5000 fatalities. Basin width 1-2 km.
- Basin thickness 1 to 1.5 km, Vs profile looks like that in SCV models. Basin-margin effects are a major cause of damage (Kawase)
- Damage also related to site conditions, less damage where soil liquefacation was greater (Tokimatsu et al.) closer to coastline.


San Jose Interchange Site: over Evergreen Basin
P A L SPORTS CENTER
PRUSCH PARK
37.34,-121.851
Google
Pointer 37°20'24.00" N 121°51'03.59" W elev 98 ft
Streaming |||||||||| 100%
Eye alt 3379 ft

- Hayward fault scenario
- SE directivity
- Enhanced motion over
- Evergreen Basin

km

N



Does Vs30 help ?

- Evergreen basin is unlikely to be well illuminated by Vs30. Slow sediments thicken away from basin margins towards center of SCV and towards San Francisco Bay. The shallow sediment over deep parts of the Evergreen basin is if anything faster than that further from Diablo hills. NGA models' dependency on Vs30 will not assist in amplifying the long-period SA median at sites over the basin.
- C.f., Campbell claim that Flatfile Vs30 is highly correlated with Z(Vs=2.5) when Z<3 km.

Statistical Comments

- Data may be consistent with tent model although consistency metric should be reviewed.
- Data may be consistent with a variety of other more realistic models
- Simplest description is not necessarily best when data are sparse and sample bias is a probable feature.
- If compelling evidence exists that simplest is wrong, it’s time to go shopping for better model.
- Cost of error is that PSHA analysis gives bad advice to construction industry about basin-related seismic hazard. Blasé attitudes could be laid at doorstep of NGA teams and USGS and others who adopt NGA models.

Epistemology

- Future F we think we know but which will never occur
- F we think we know which will occur
- F we know we are guessing about but happen to be guessing well
- F we know we are guessing about and we are guessing poorly
- F we acknowledge to be a mystery and try to cover all bases with a logic tree
- Reports we agree or contract to make: assessments of future ground motion at site S.