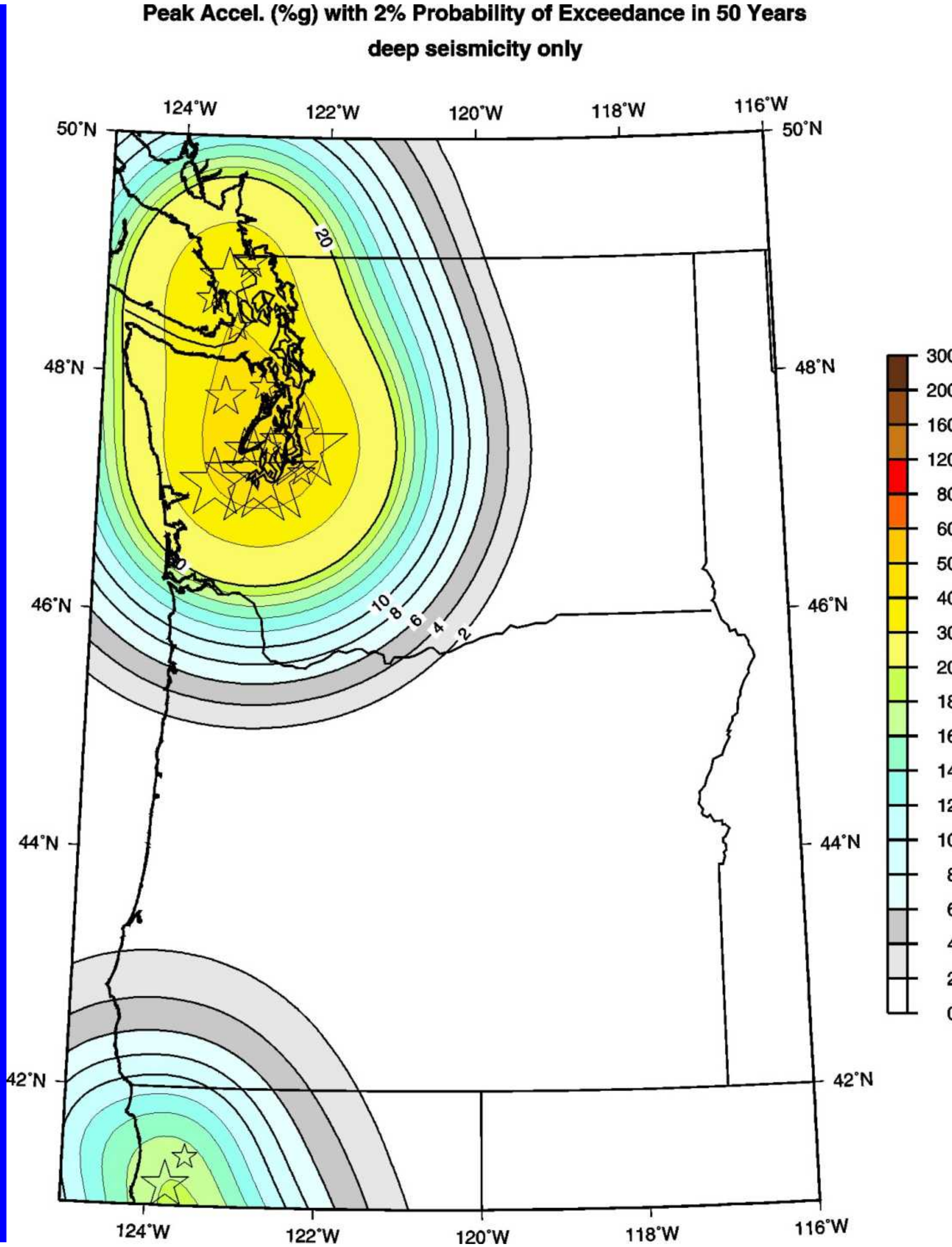
Day 2 Presentations

Art Frankel

USGS

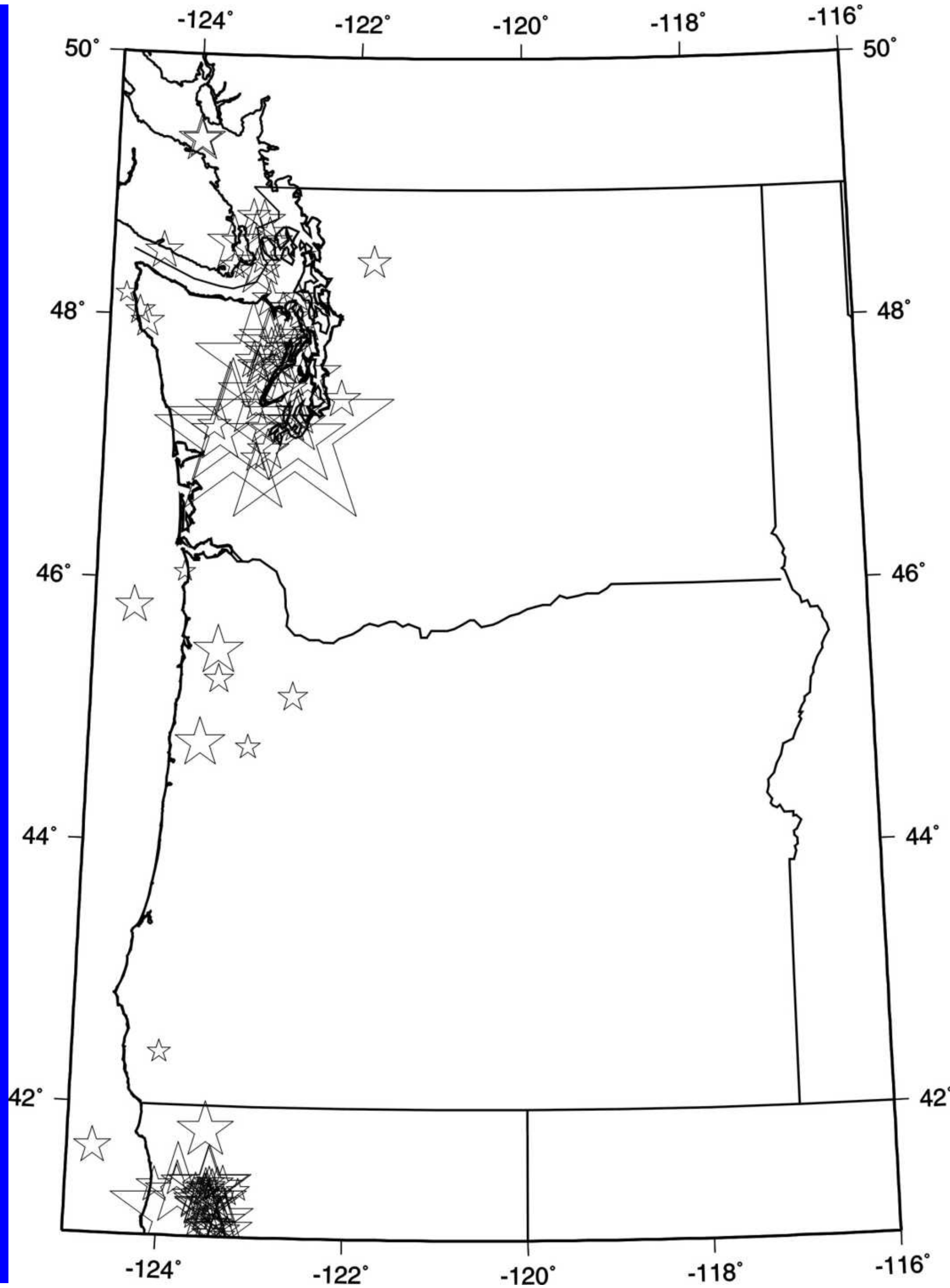
With contributions from Steve Harmsen and Charles Mueller

Intra-Slab Earthquakes



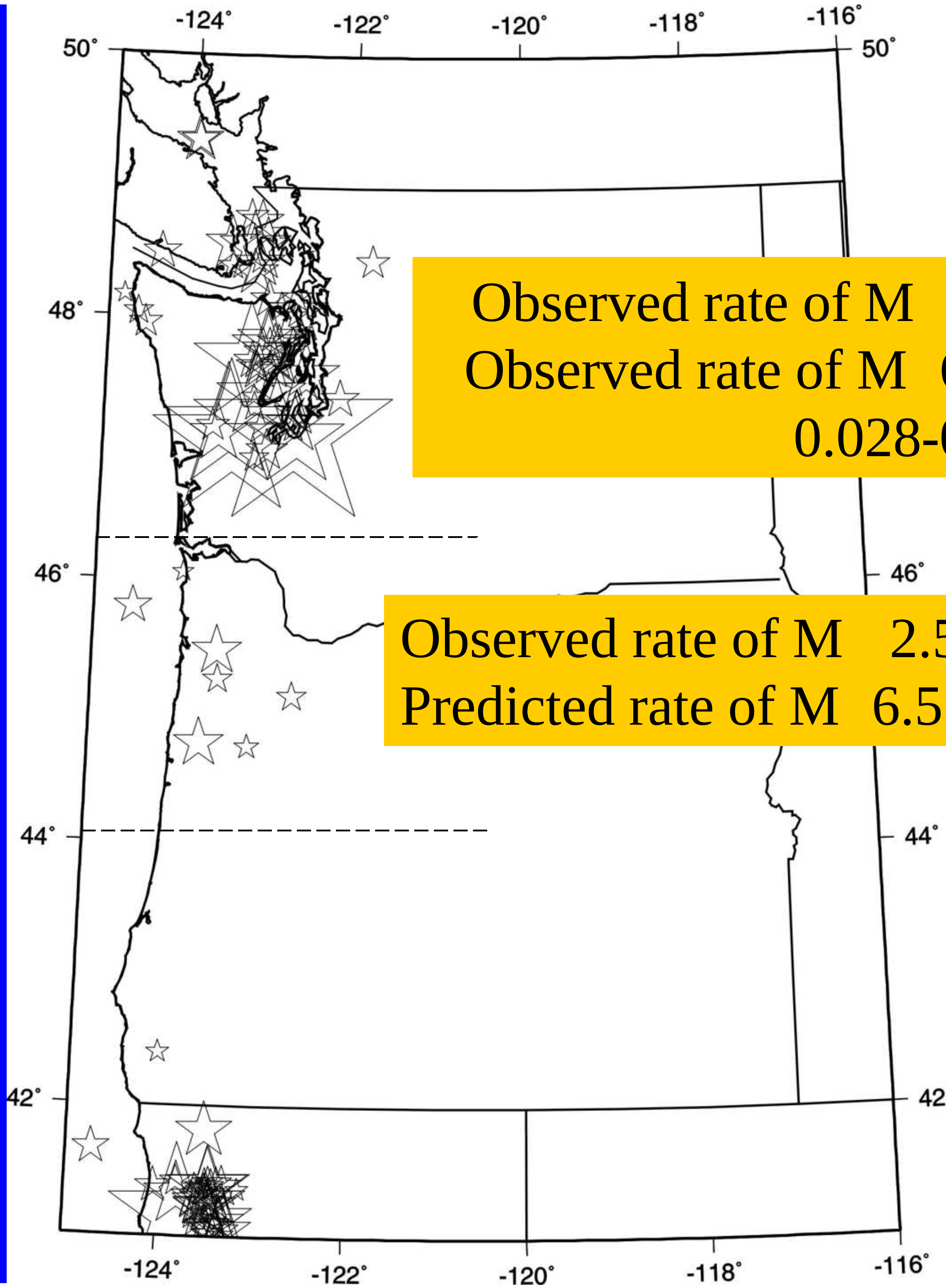
M 4.0 since 1963
M 6.0 since 1940

b= 0.40
Mmax= 7.2



Mag 2.5
Depth 35 km
since 1990

From ANSS catalog

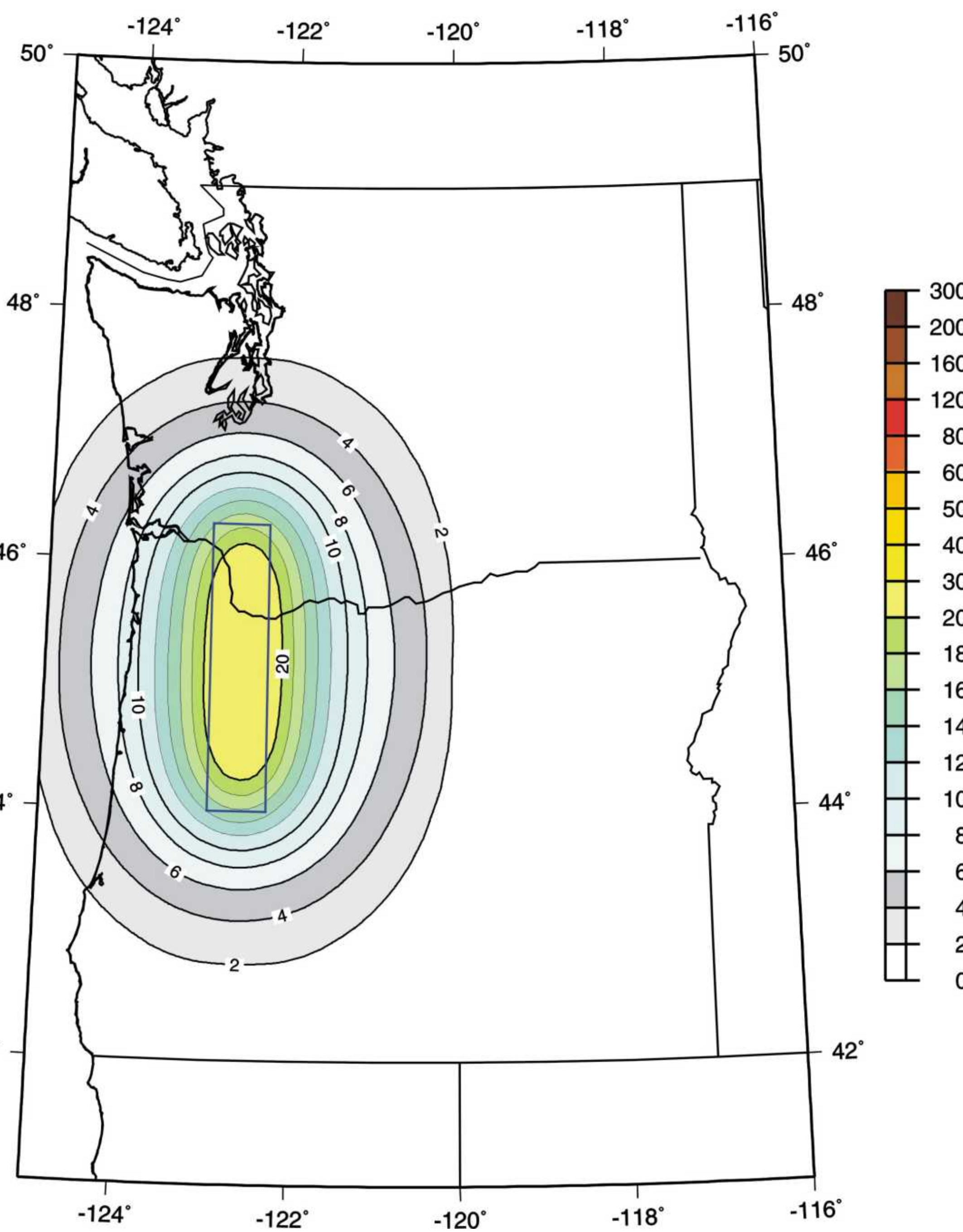


Observed rate of M 2.5 since 1990: 3.4 /yr
Observed rate of M 6.5 since 1940 or 1900: 0.028-0.045 /yr

Observed rate of M 2.5 since 1990: 0.38 /yr
Predicted rate of M 6.5: 0.003-0.005 /yr

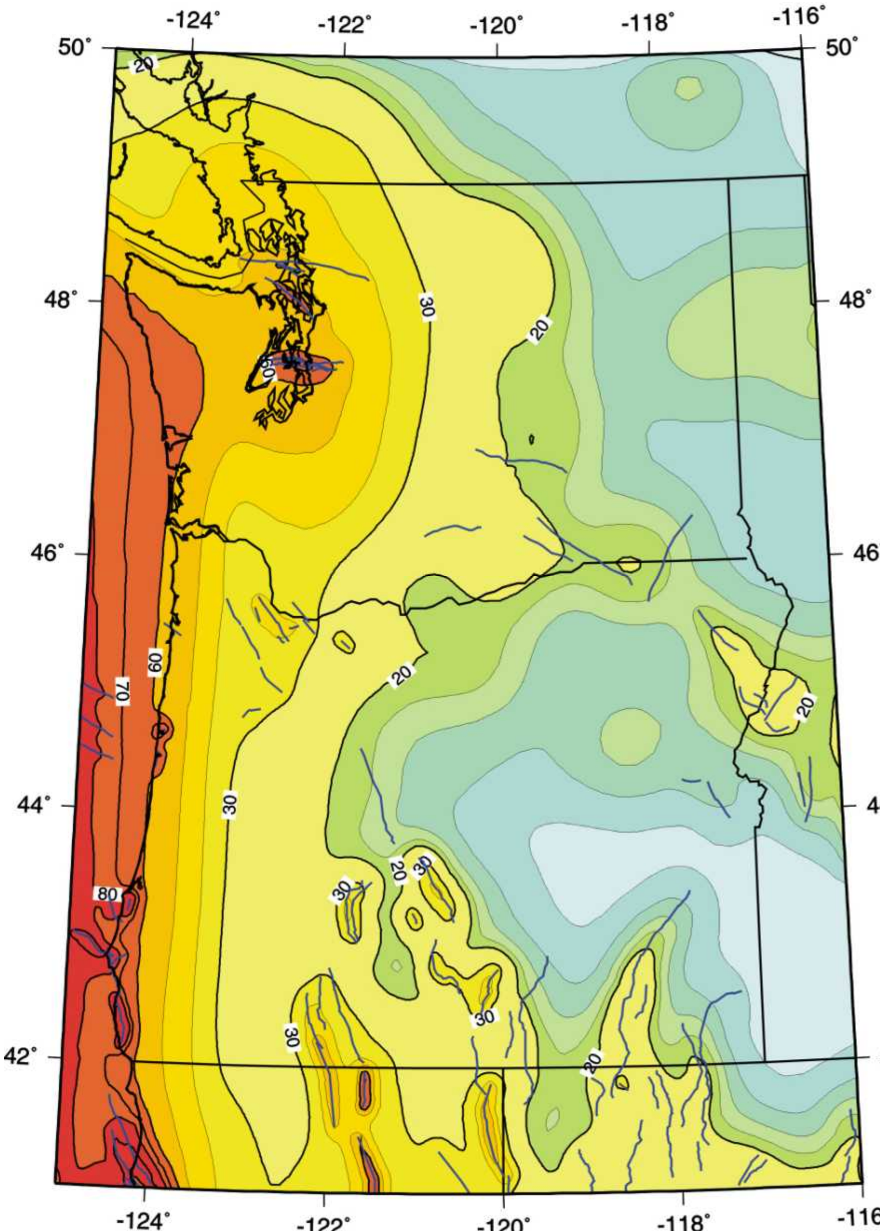
USGS science for a changing world

Peak Accel. (%g) with 2% Probability of Exceedance in 50 Years

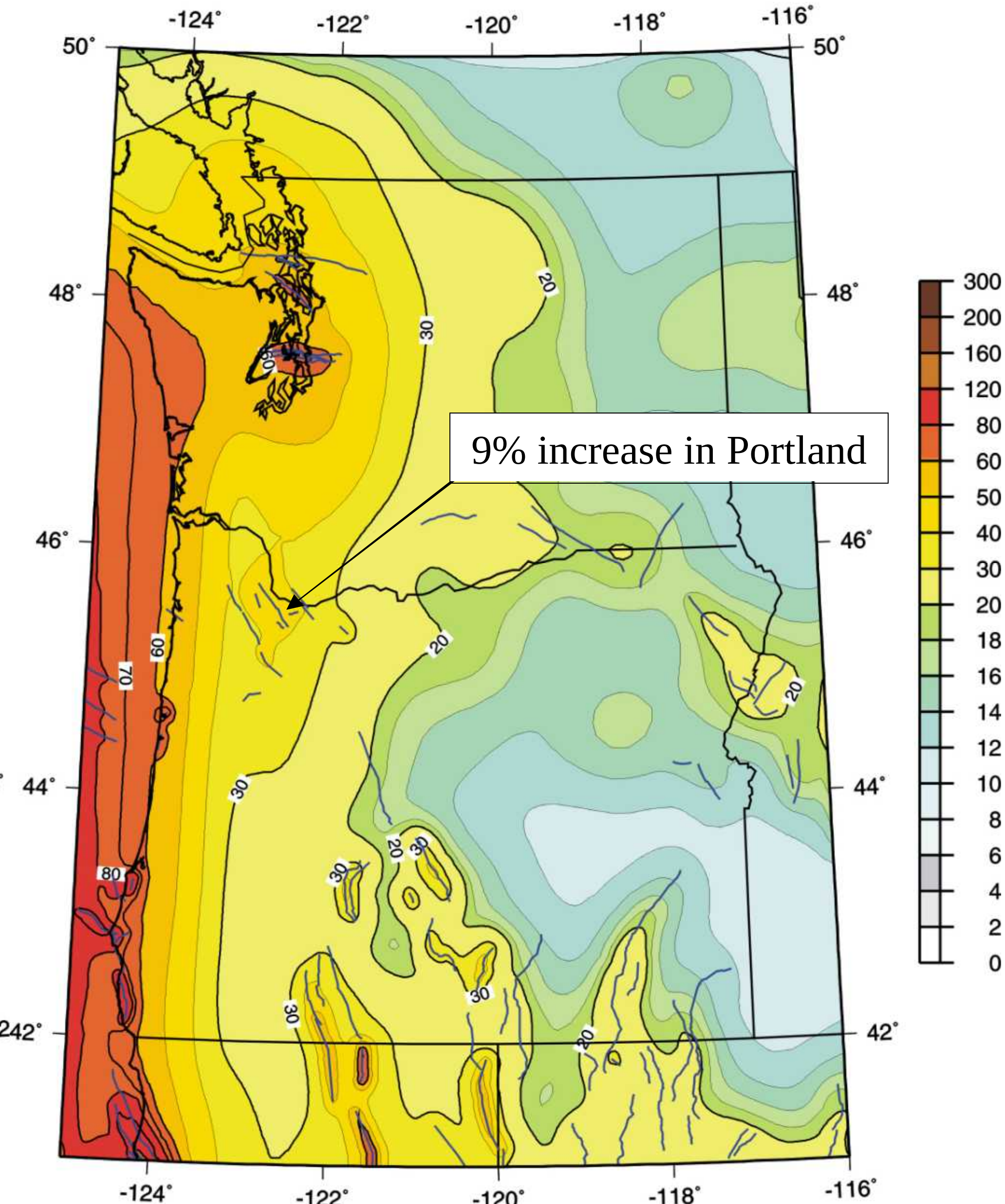


Deep zone only

Peak Accel. (%g) with 2% Probability of Exceedance in 50 Years
USGS Map, Oct. 2002



Peak Accel. (%g) with 2% Probability of Exceedance in 50 Years



USGS science for a changing world

2002 map

2002 map + Portland deep zone

Ground-motion prediction (attenuation) relations

- Maps are for a NEHRP BC site condition: Vs30= 760 m/s

WUS Attenuation relations used in 2002 maps for shallow faulting (equal weights)

- Boore et al. (1997), specified for Vs30= 760 m/s
- Sadigh et al. (1997) “rock” site relations
- Abrahamson and Silva (1997) “rock” site relations
- Campbell and Bozorgnia (2003), with their recommendation for BC sites
- Spudich et al. (1999) “rock” site relations (used for extensional areas only)

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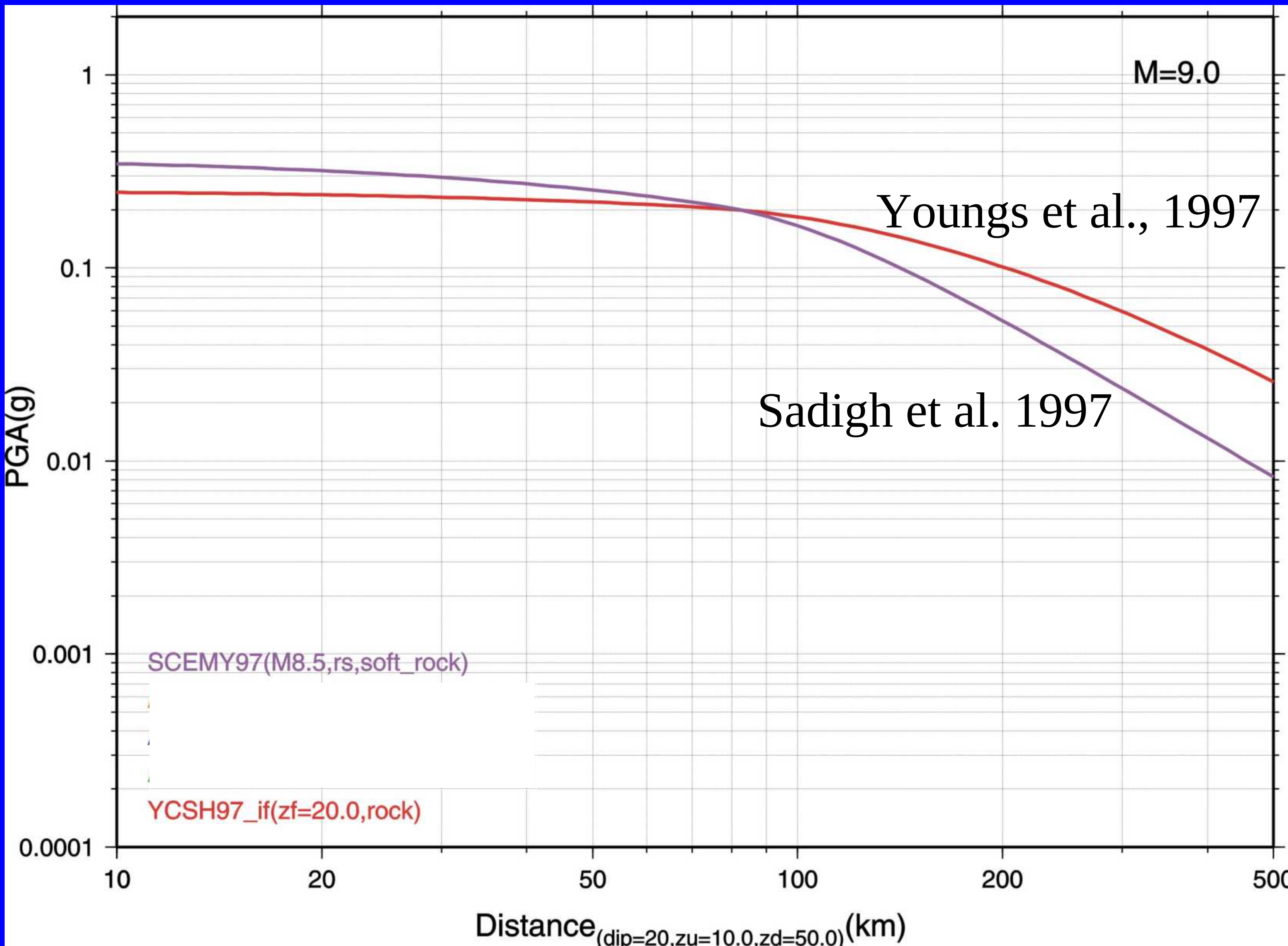
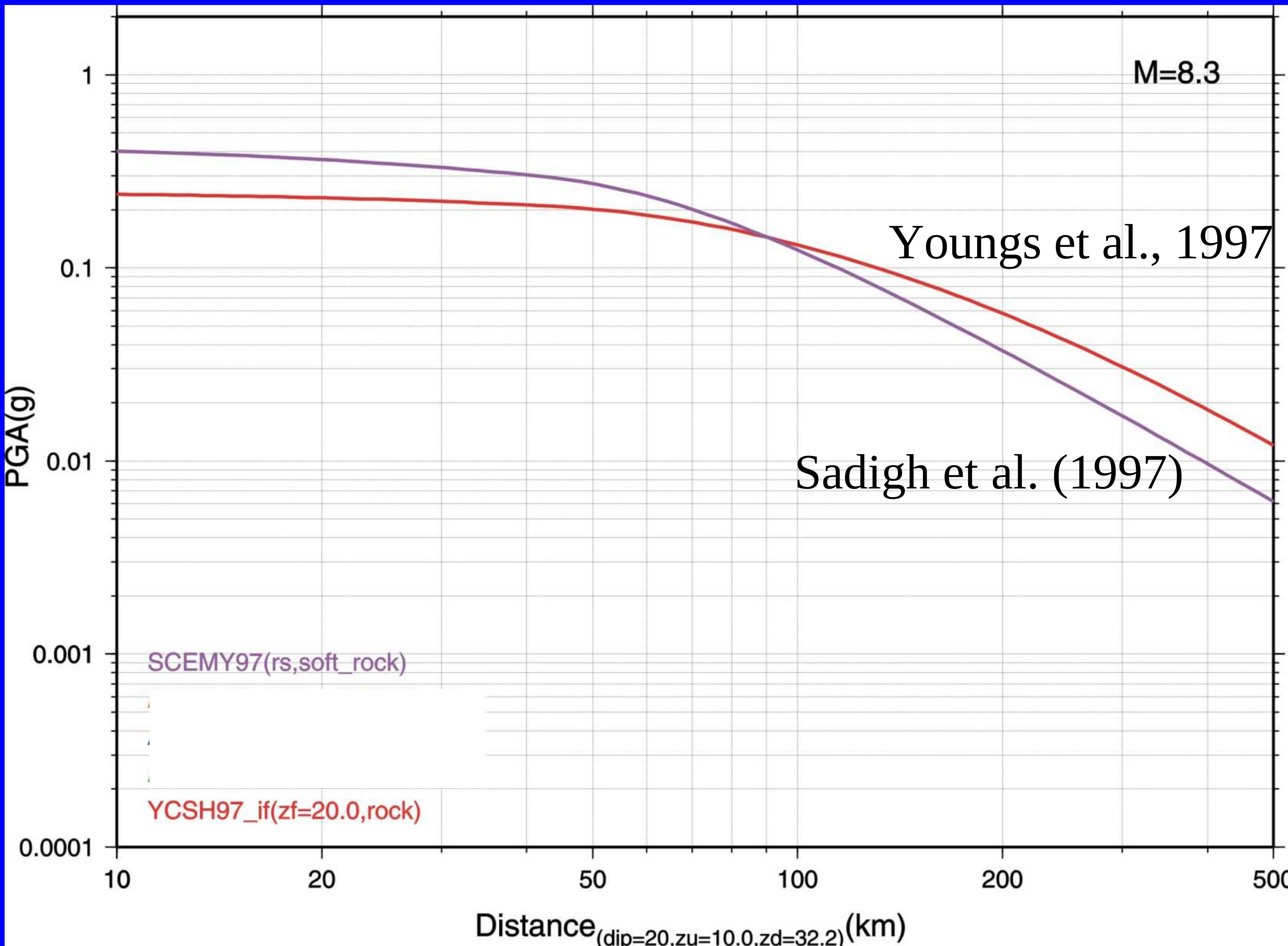
Attenuation relations used in 2002 maps for Benioff-zone earthquakes

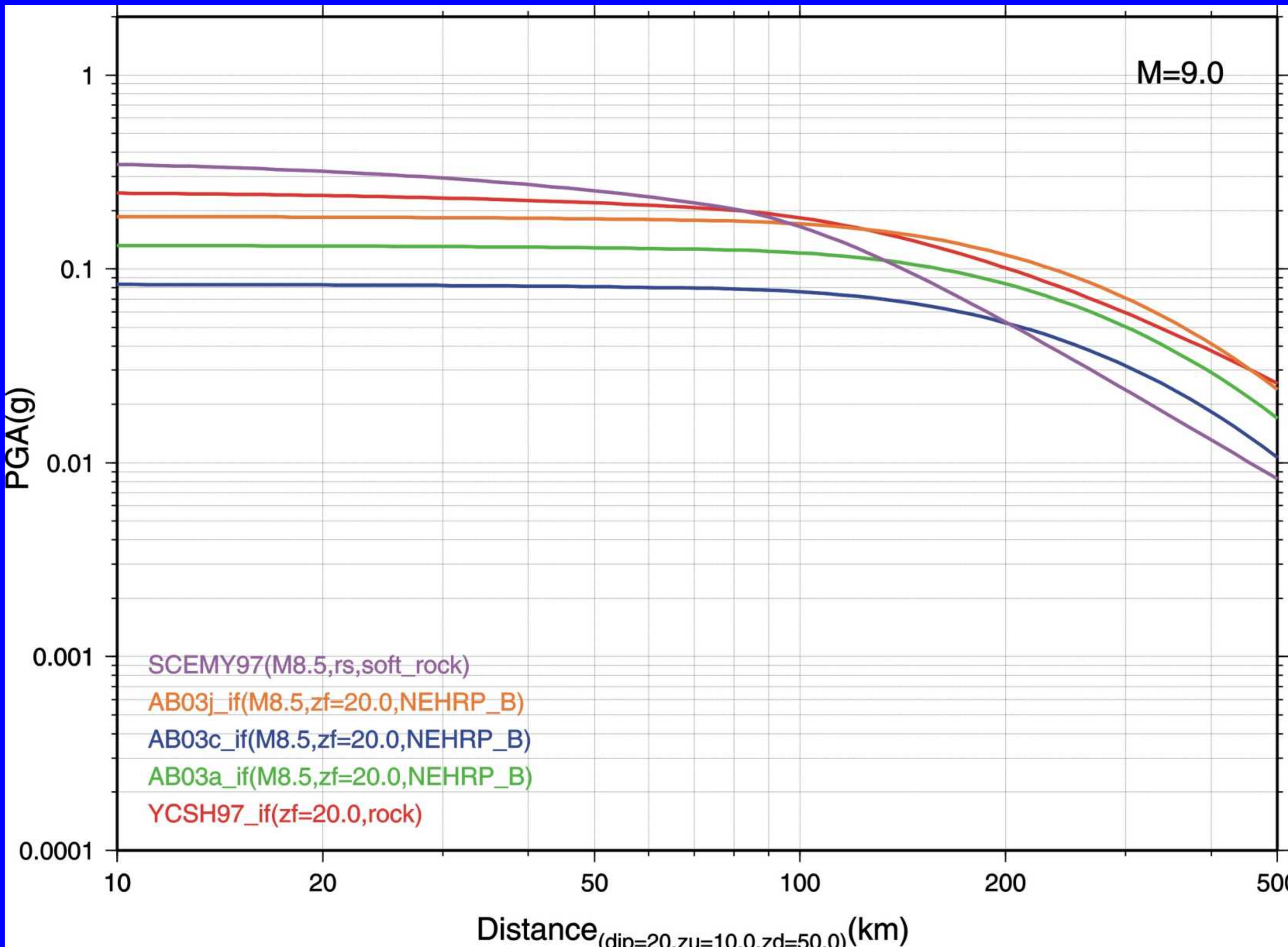
- Youngs et al. (1997) rock site, intraslab, 0.5 wt
- Atkinson and Boore (2002) for global intraslab eq data set (BC ave), 0.25 wt
- Atkinson and Boore (2002) for Cascadia intraslab eq data set (BC ave), 0.25 wt

Attenuation relations used in 2002 maps for subduction-zone earthquakes

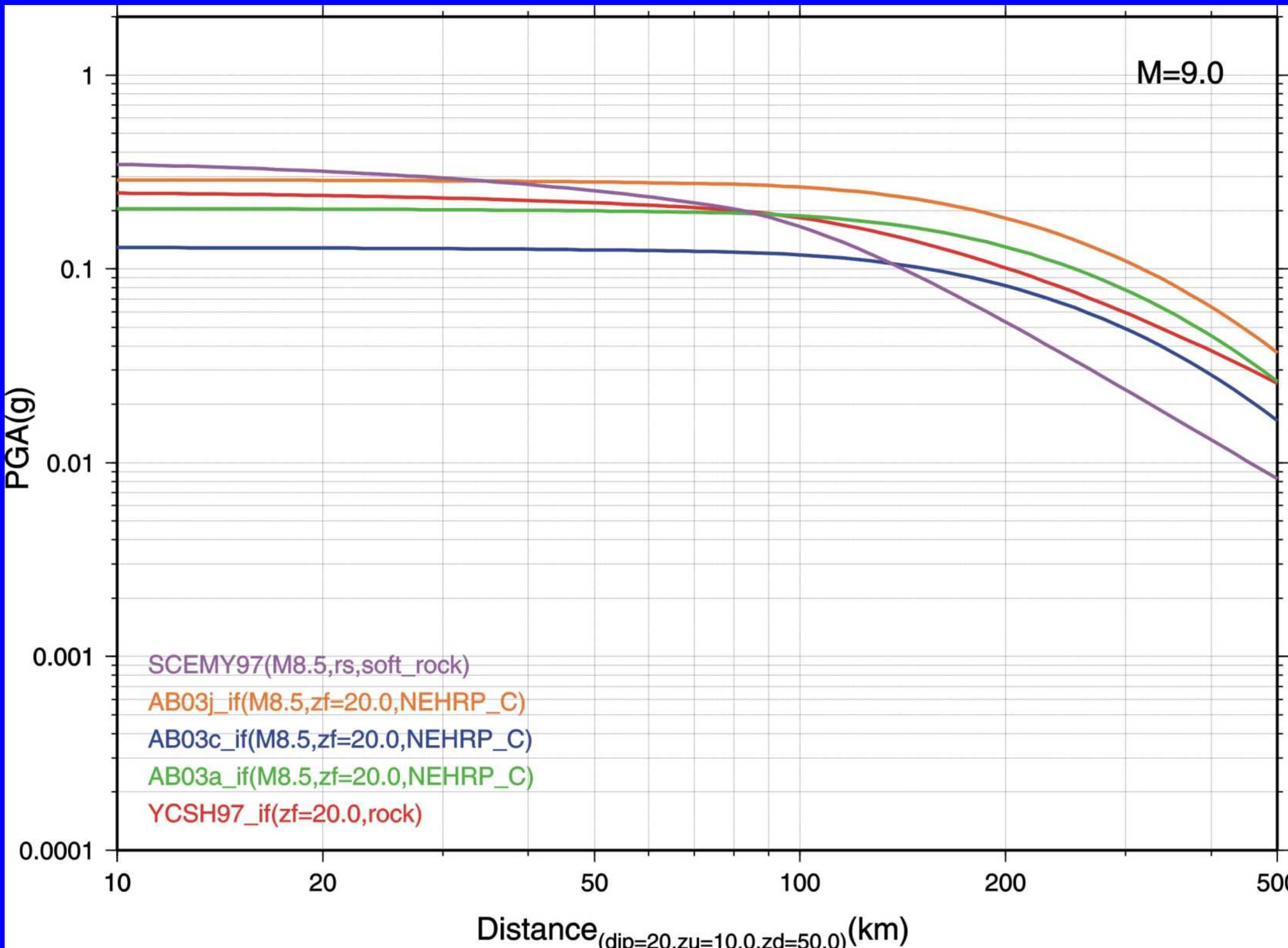
- Youngs et al. (1997) interface eq's, rock sites
- Sadigh et al. (1997) crustal eq's, rock sites
- Give equal weight for distances < 70 km where Sadigh et al. has larger PGA's, give full weight to Youngs et al. at larger distances

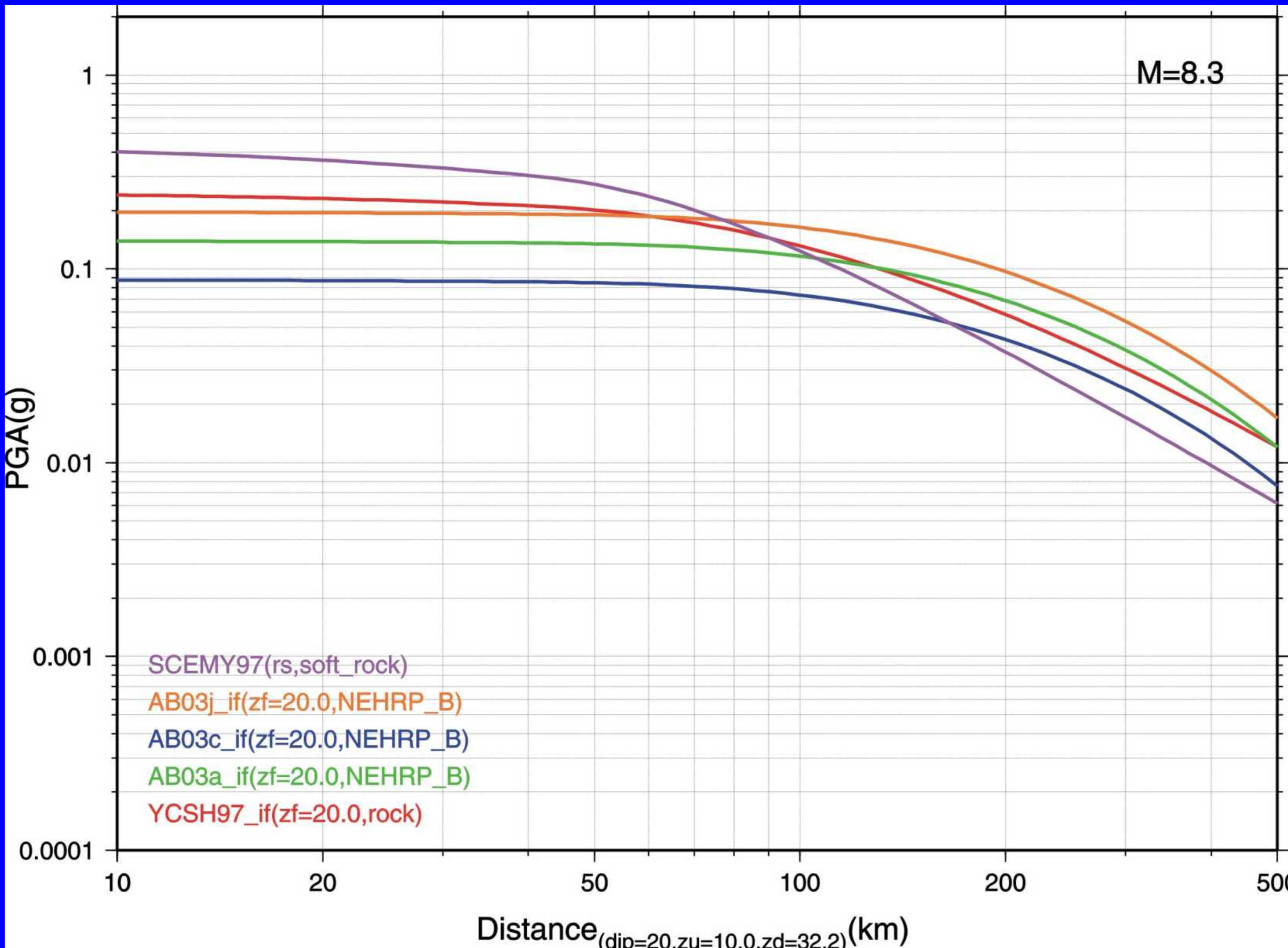

M=9.0
Youngs et al., 1997
Sadigh et al. 1997
PGA(g)
1
0.1
0.01
0.001
0.0001
SCEMY97(M8.5,rs,soft_rock)
YCSH97_if(zf=20.0,rock)
10
20
50
100
200
500
Distance(dip=20,zu=10.0,zd=50.0)(km)


M=8.3
Youngs et al., 1997
Sadigh et al. (1997)
PGA(g)
1
0.1
0.01
0.001
0.0001
10
20
50
100
200
500
Distance(dip=20,zu=10.0,zd=32.2)(km)
SCEMY97(rs,soft_rock)
YCSH97_if(zf=20.0,rock)

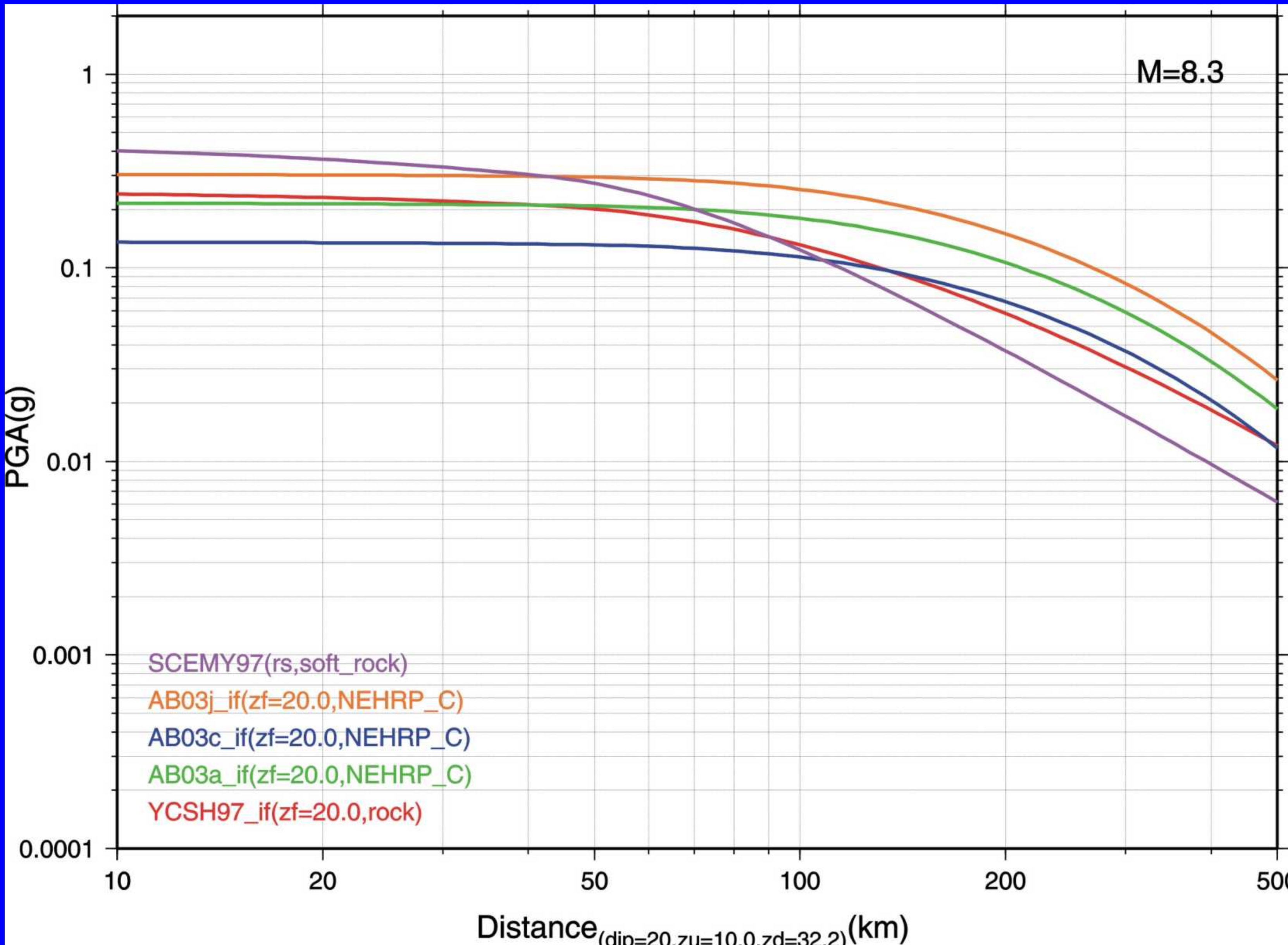


M=9.0
PGA(g)
1
0.1
0.01
0.001
0.0001
10
20
50
100
200
500
Distance(dip=20,zu=10.0,zd=50.0)(km)
SCEMY97(M8.5,rs,soft_rock)
AB03j_if(M8.5,zf=20.0,NEHRP_B)
AB03c_if(M8.5,zf=20.0,NEHRP_B)
AB03a_if(M8.5,zf=20.0,NEHRP_B)
YCSH97_if(zf=20.0,rock)


M=9.0
PGA(g)
1
0.1
0.01
0.001
0.0001
10
20
50
100
200
500
Distance(dip=20,zu=10.0,zd=50.0)(km)
SCEMY97(M8.5,rs,soft_rock)
AB03j_if(M8.5,zf=20.0,NEHRP_C)
AB03c_if(M8.5,zf=20.0,NEHRP_C)
AB03a_if(M8.5,zf=20.0,NEHRP_C)
YCSH97_if(zf=20.0,rock)

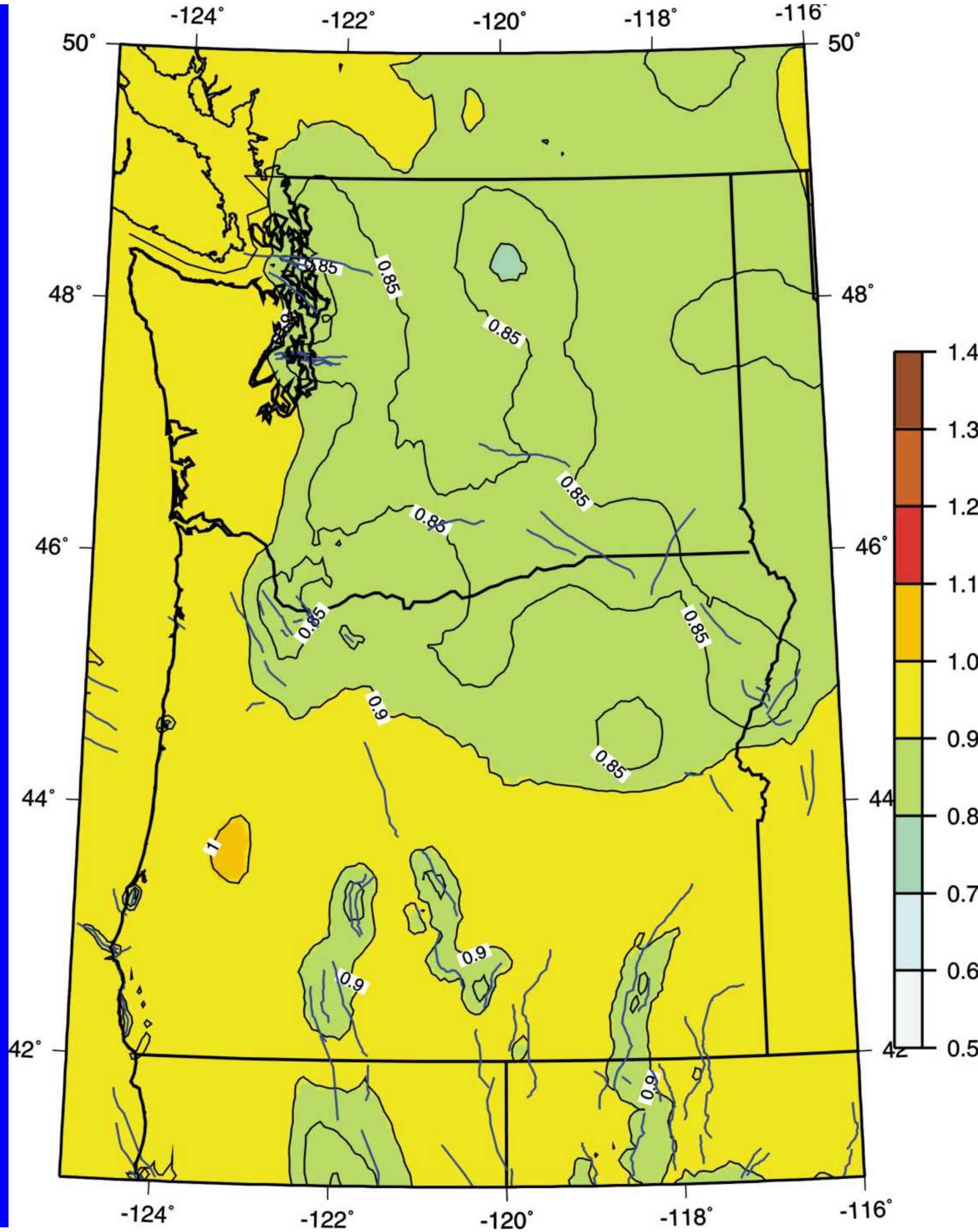


M=8.3
PGA(g)
1
0.1
0.01
0.001
0.0001
SCEMY97(rs,soft_rock)
AB03j_if(zf=20.0,NEHRP_B)
AB03c_if(zf=20.0,NEHRP_B)
AB03a_if(zf=20.0,NEHRP_B)
YCSH97_if(zf=20.0,rock)
10
20
50
100
200
500
Distance(dip=20,zu=10.0,zd=32.2)(km)



M=8.3
PGA(g)
1
0.1
0.01
0.001
0.0001
10
20
50
100
200
500
Distance(dip=20,zu=10.0,zd=32.2)(km)
SCEMY97(rs,soft_rock)
AB03j_if(zf=20.0,NEHRP_C)
AB03c_if(zf=20.0,NEHRP_C)
AB03a_if(zf=20.0,NEHRP_C)
YCSH97_if(zf=20.0,rock)

Comparisons between hazard maps made with NGA (Vs30= 760 m/s) and the 2002 hazard maps



NGA/2002 maps

5 Hz S.A.

2%PE in 50 yr

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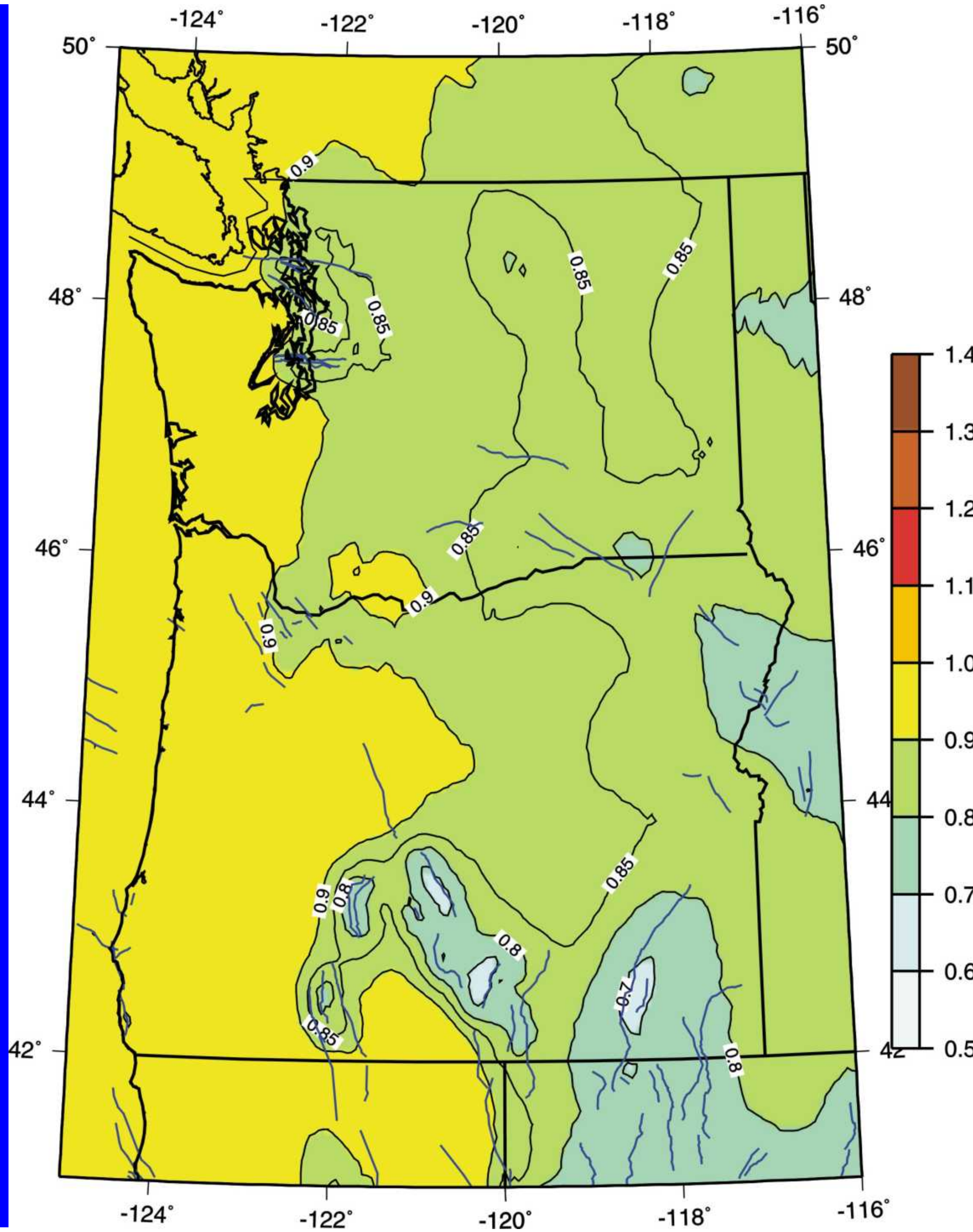
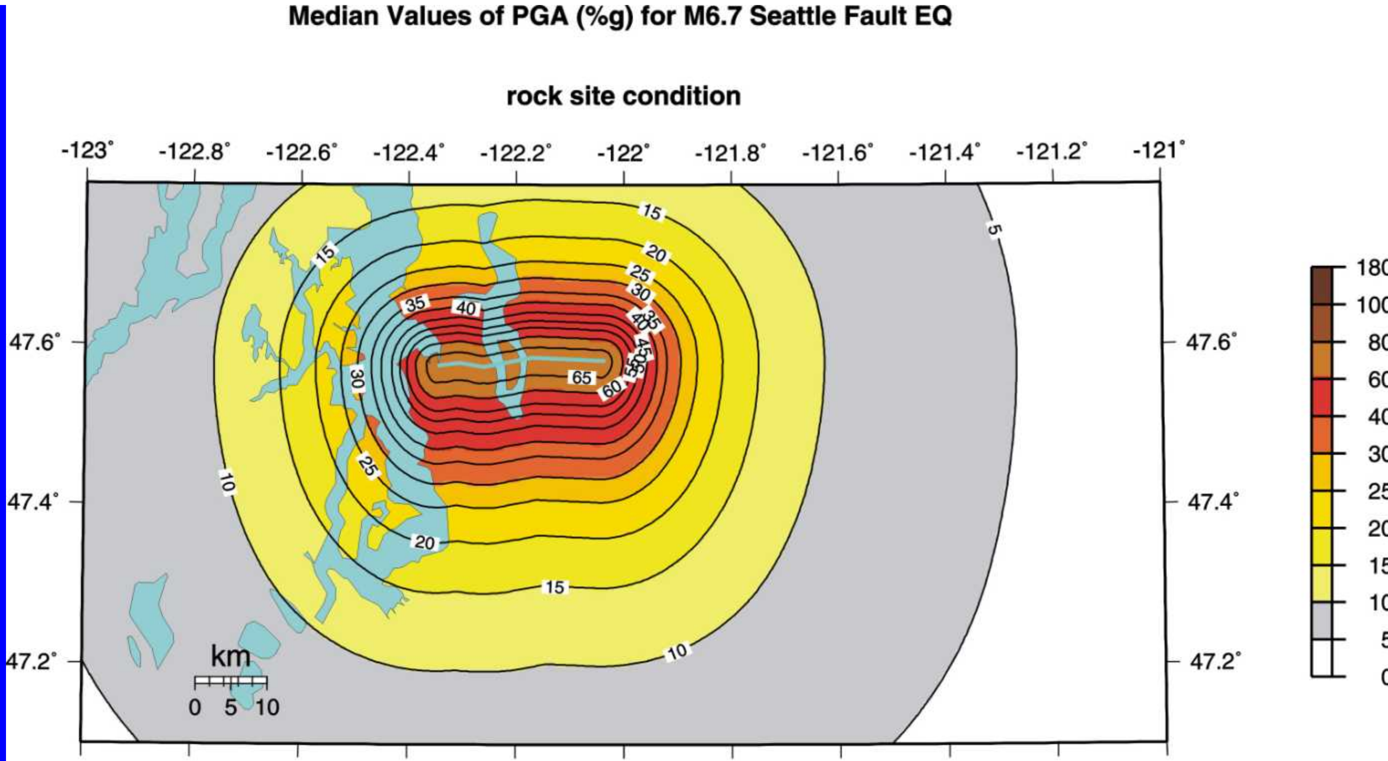


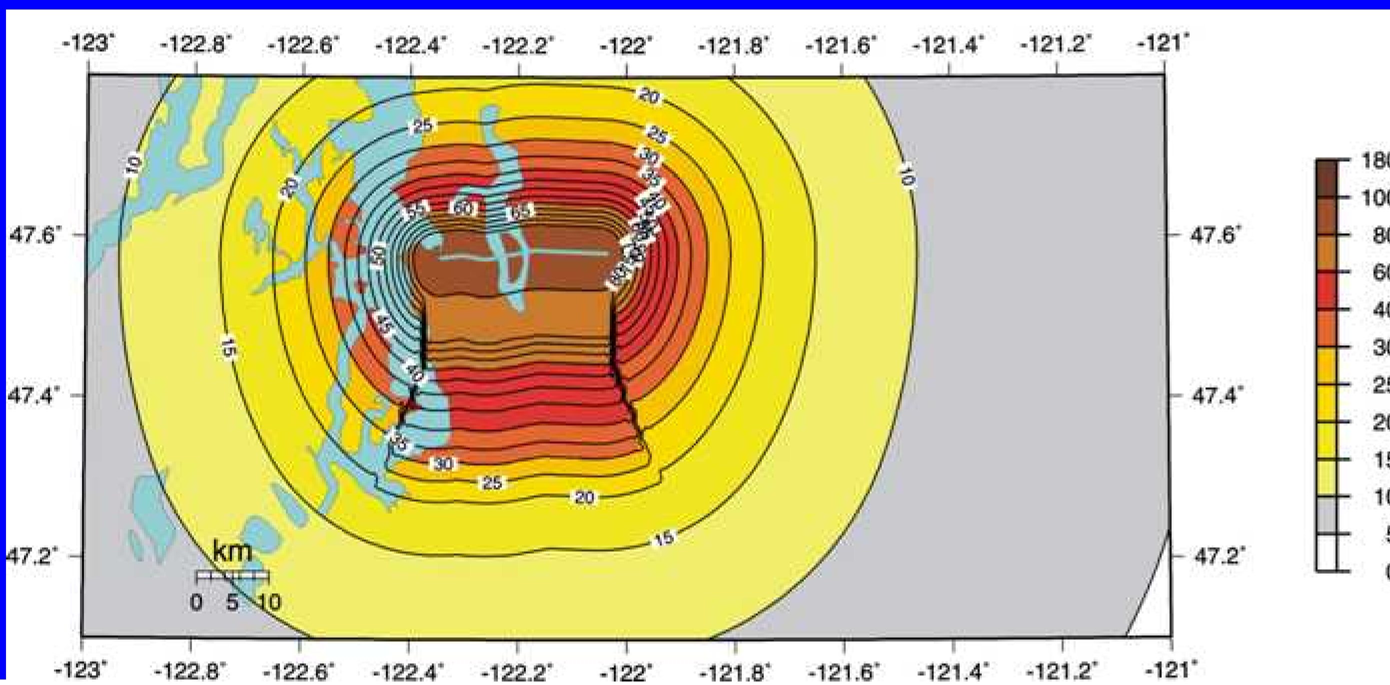
NGA/2002 maps

1 Hz S.A.

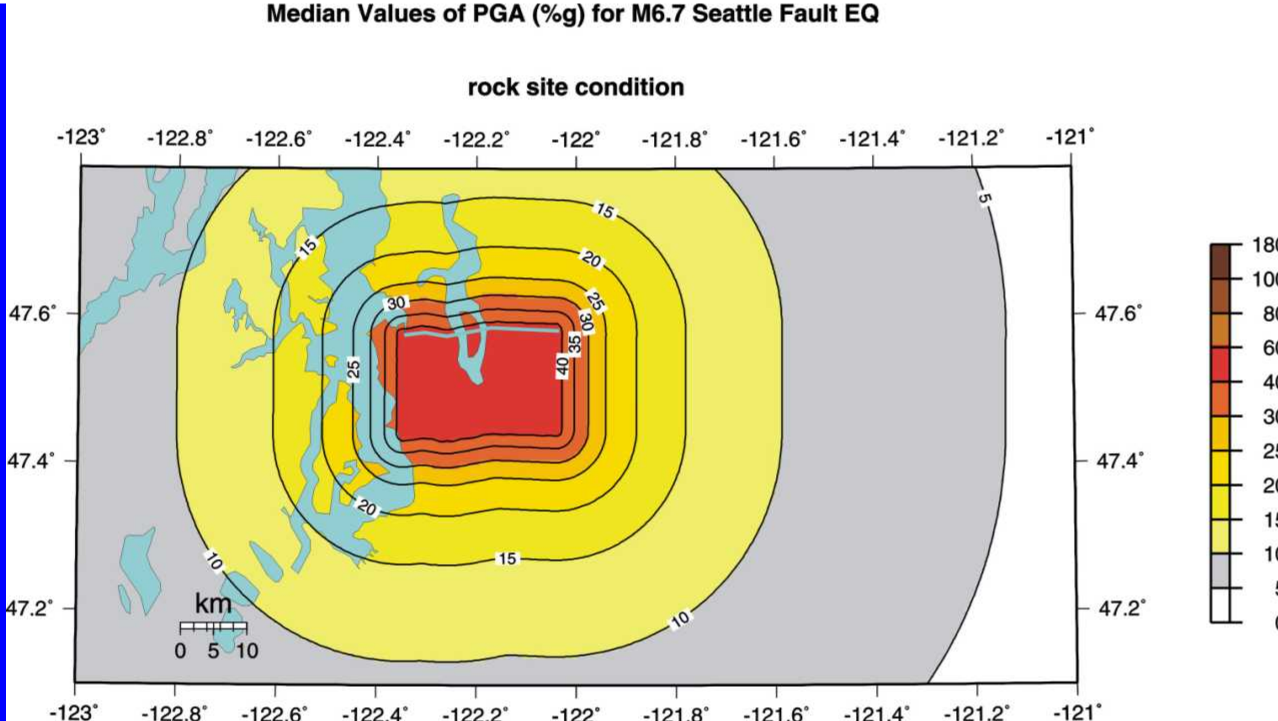
2%PE in 50 yr



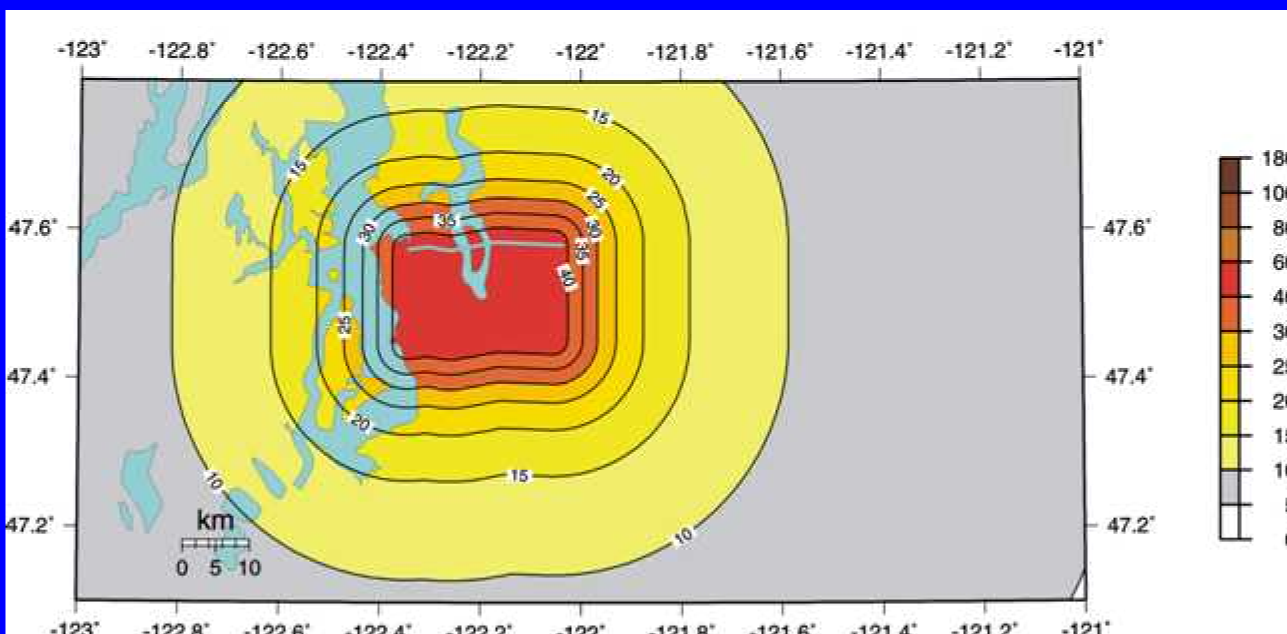
Abrahamson and Silva, NGA



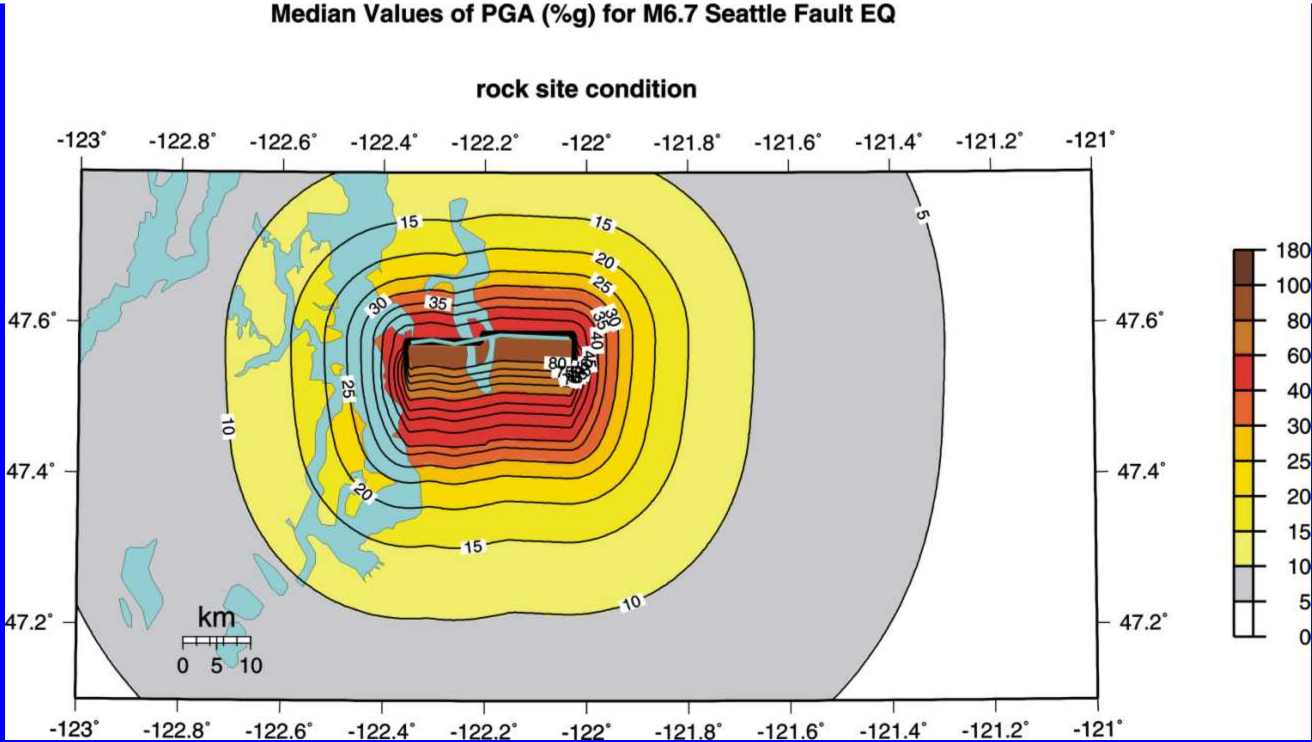
Abrahamson and Silva, 1997



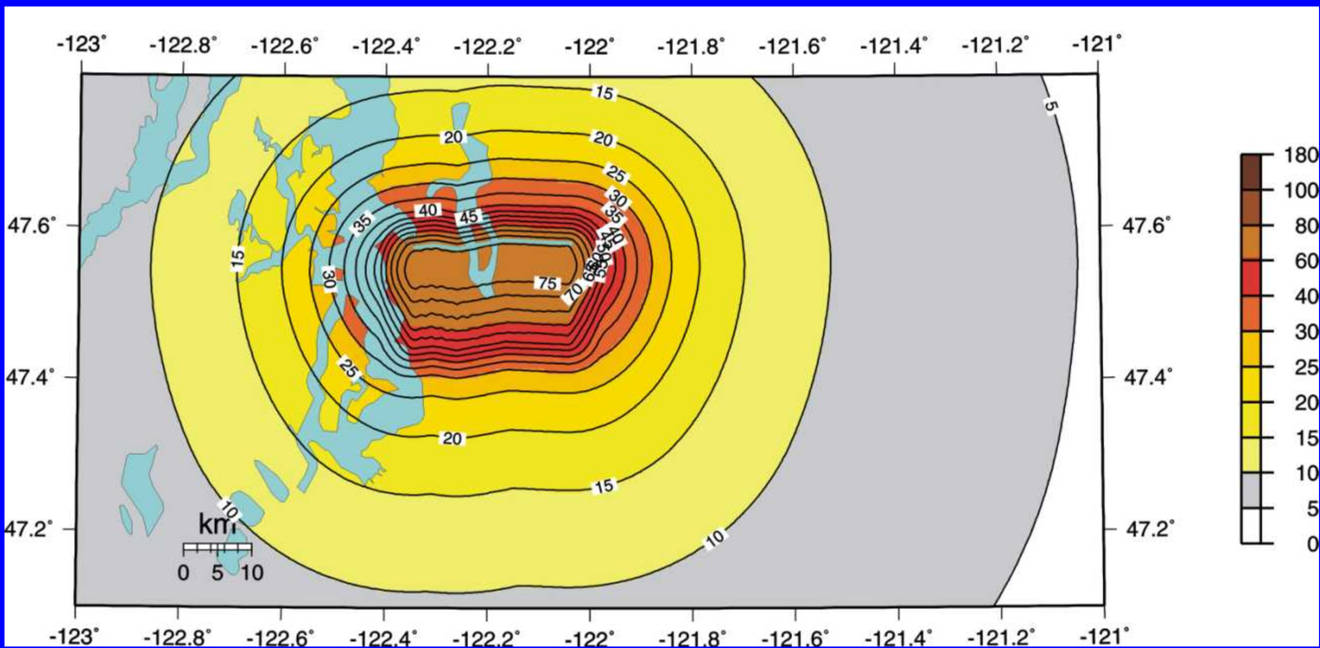
Boore and Atkinson, NGA



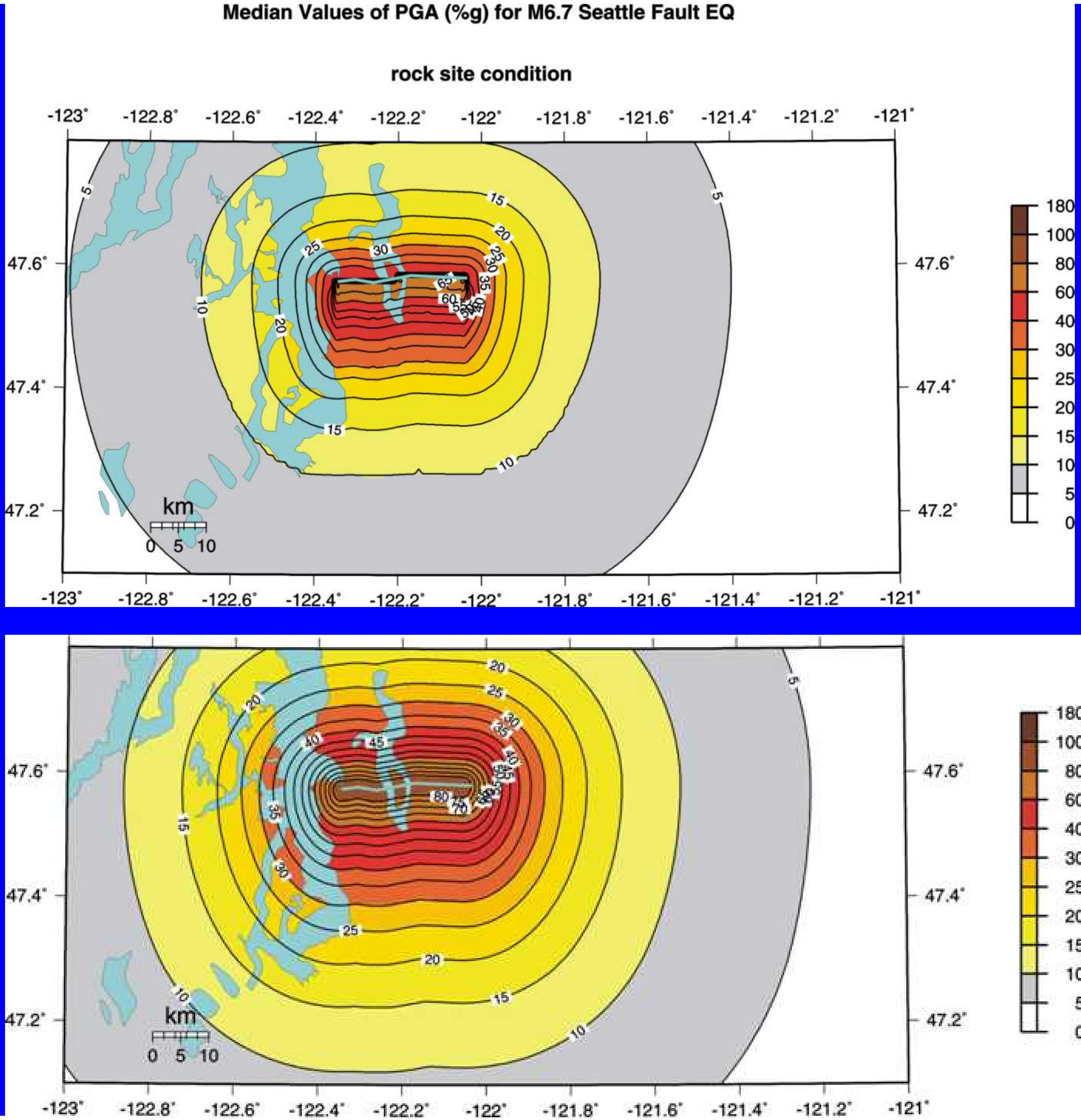
Boore, Joyner, Fumal, 1997



Campbell and Bozorgnia, NGA



Campbell and Bozorgnia, 2003

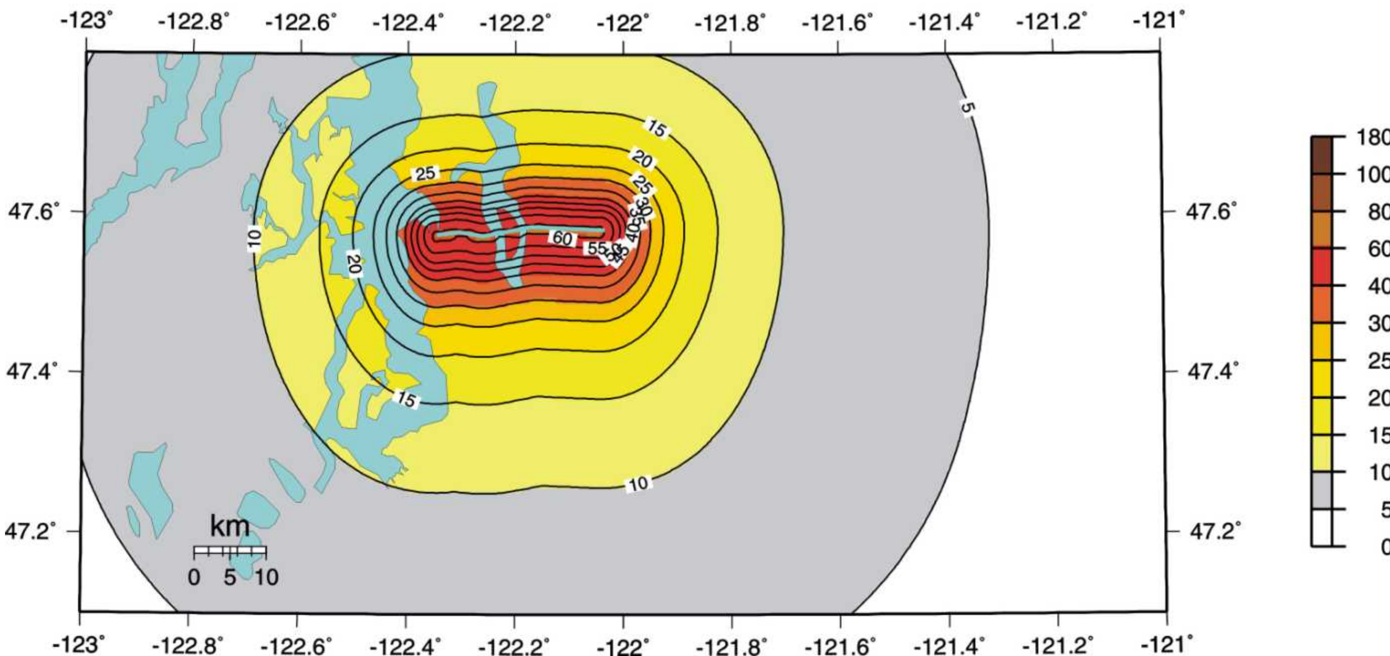


Chiou and Youngs NGA

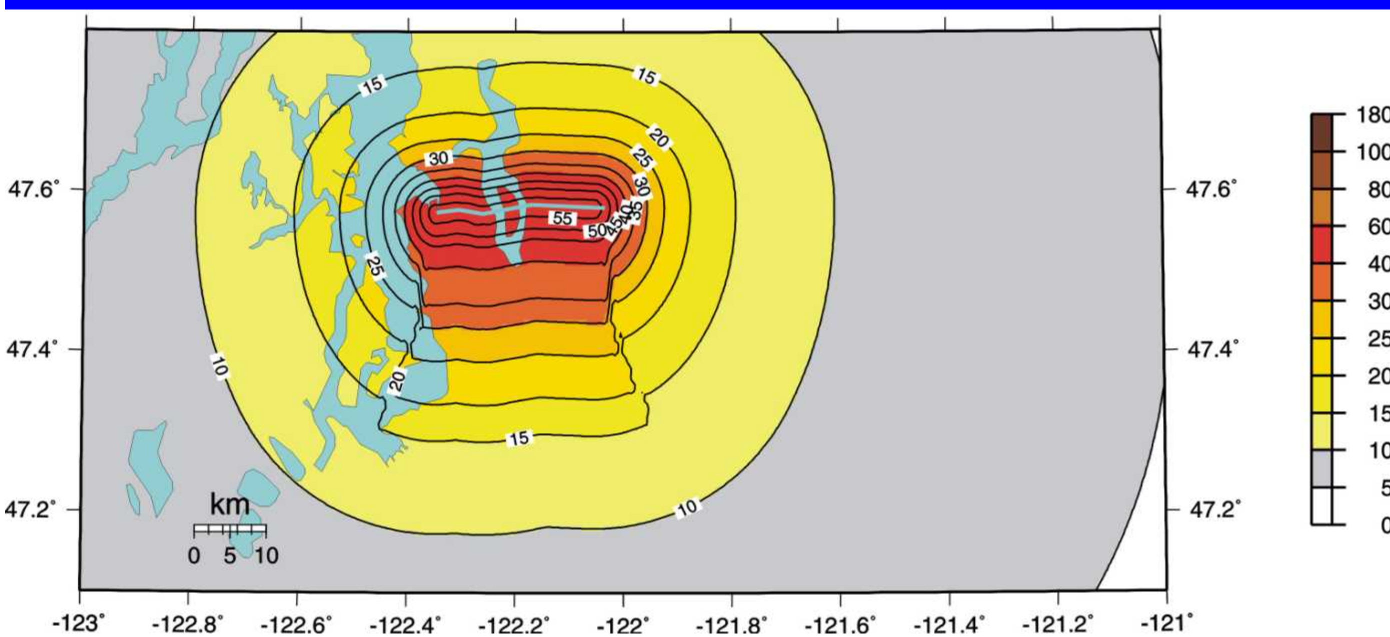
Sadigh et al. 1997

Median Values of 1 Hz S.A. (%g) for M6.7 Seattle Fault EQ

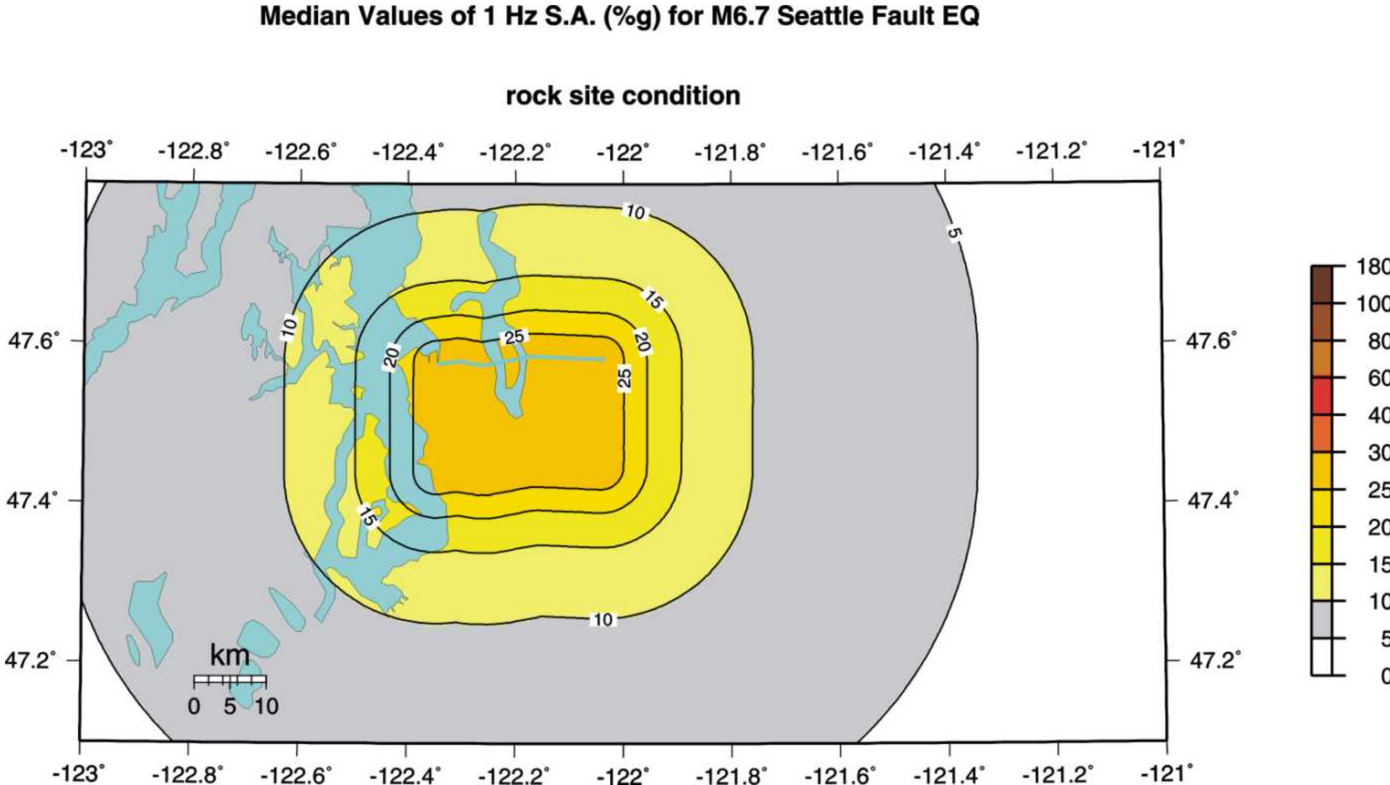
rock site condition



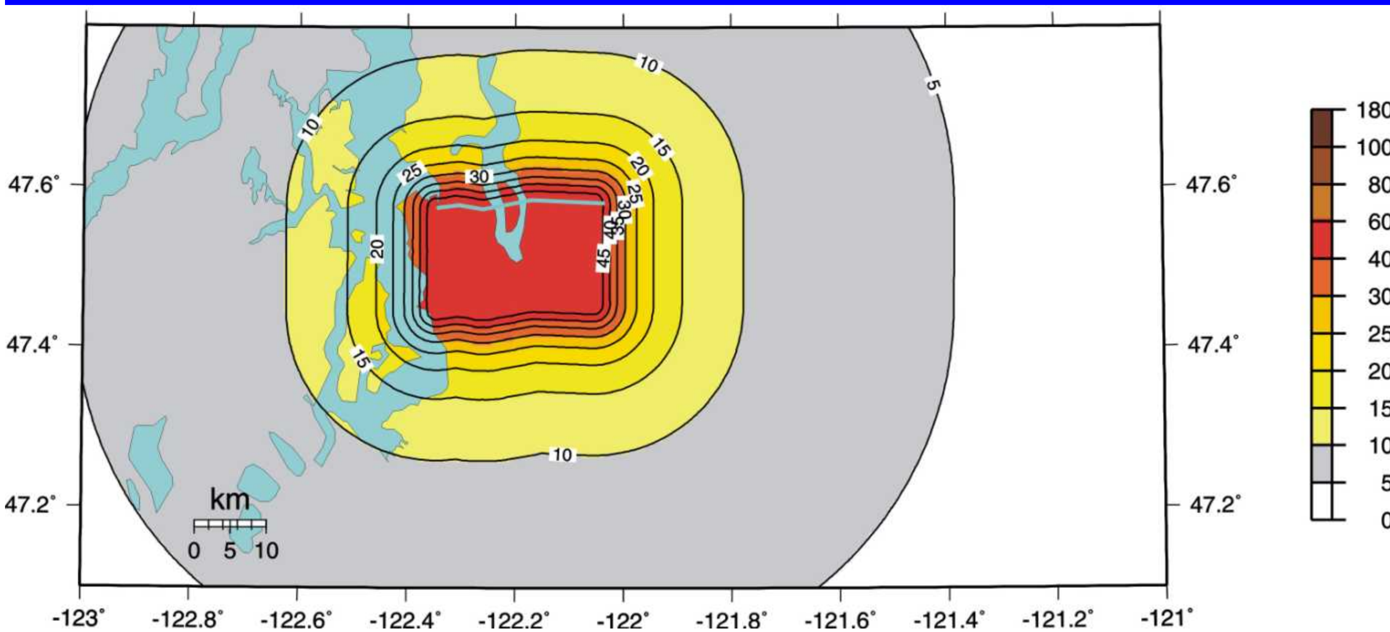
Abrahamson and Silva, NGA



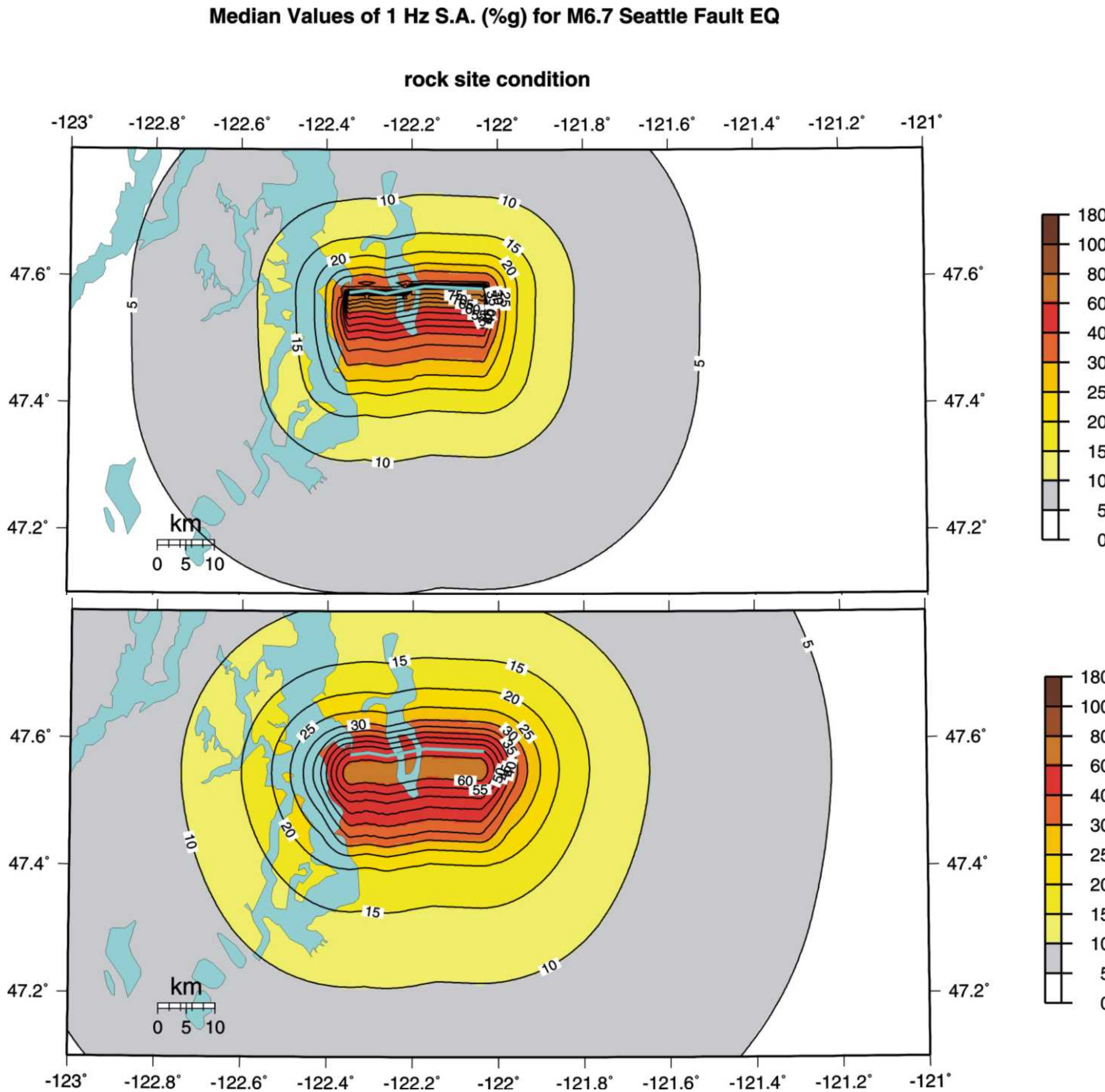
Abrahamson and Silva, 1997



Boore and Atkinson, NGA



Boore, Joyner, Fumal, 1997



Campbell and Bozorgnia, NGA

Campbell and Bozorgnia, 2003

Median Values of 1 Hz S.A. (%g) for M6.7 Seattle Fault EQ

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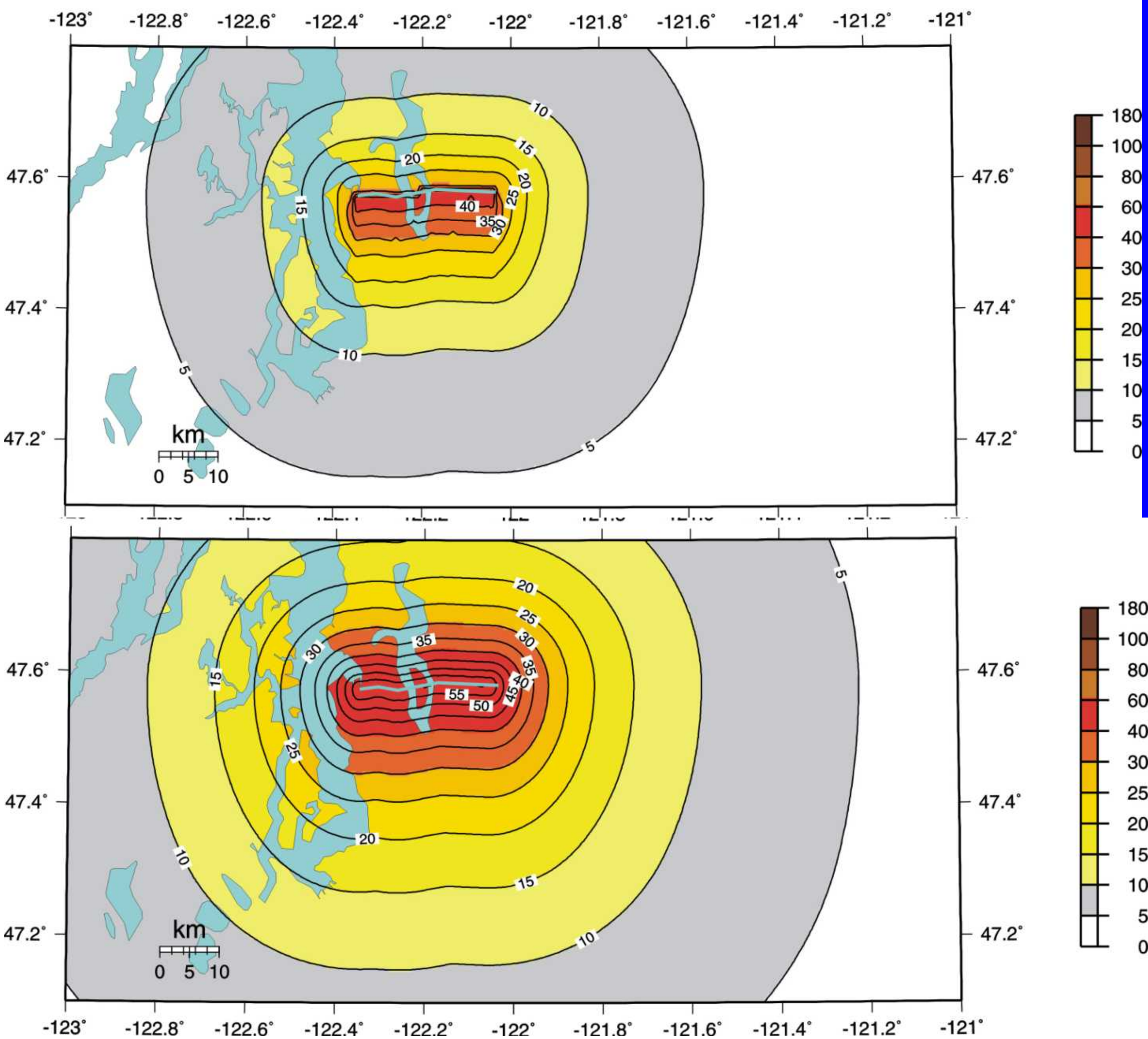
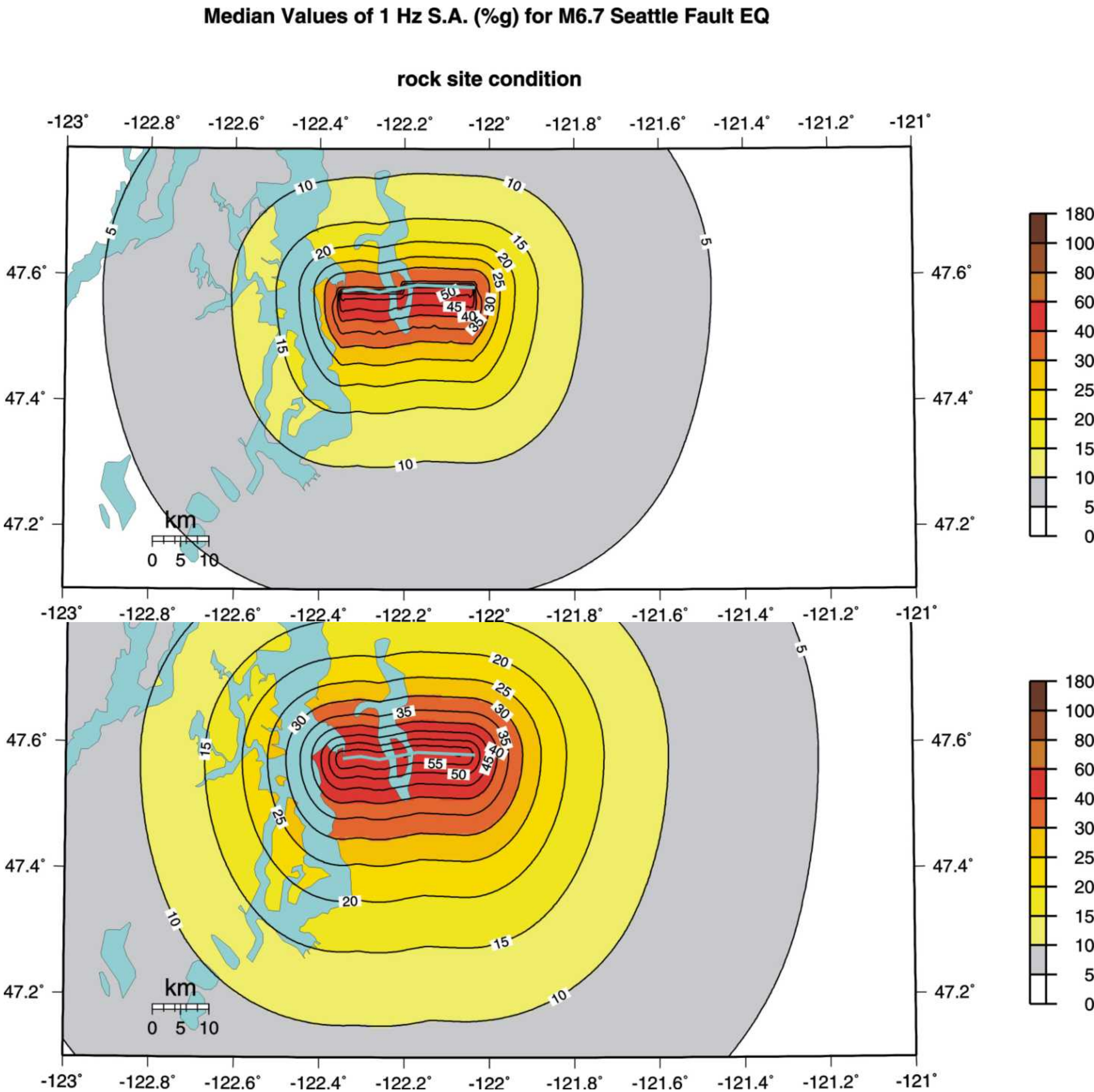


Chiou and Youngs NGA

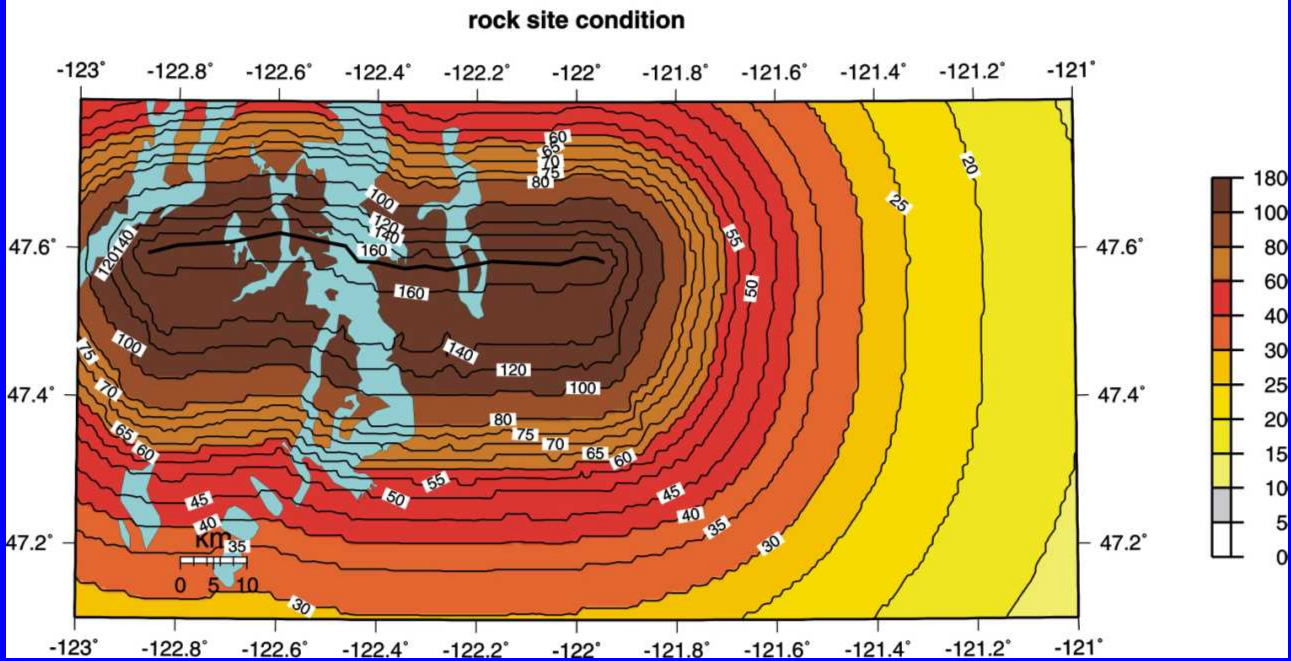
Sadigh et al. 1997



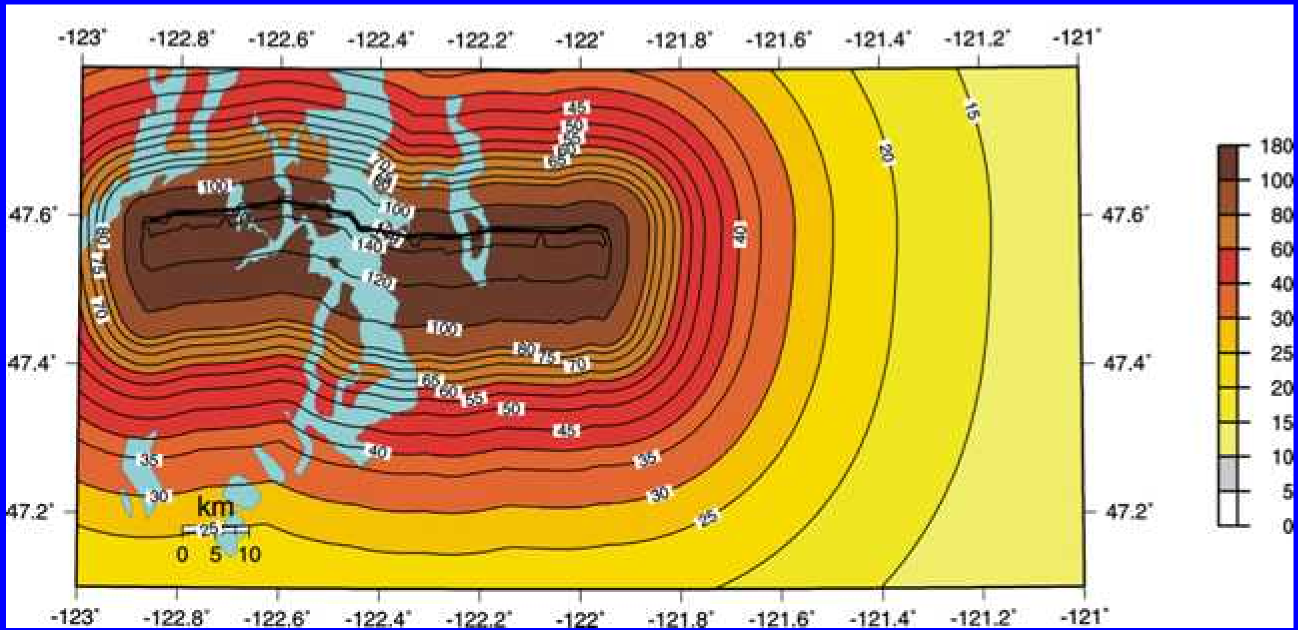
Chiou and Youngs NGA, Vs30= 620 m/s

Sadigh et al. 1997

M7.2 Seattle Fault EQ, median 5 Hz S.A.(%g)



Atten. relations Used in 2002 maps

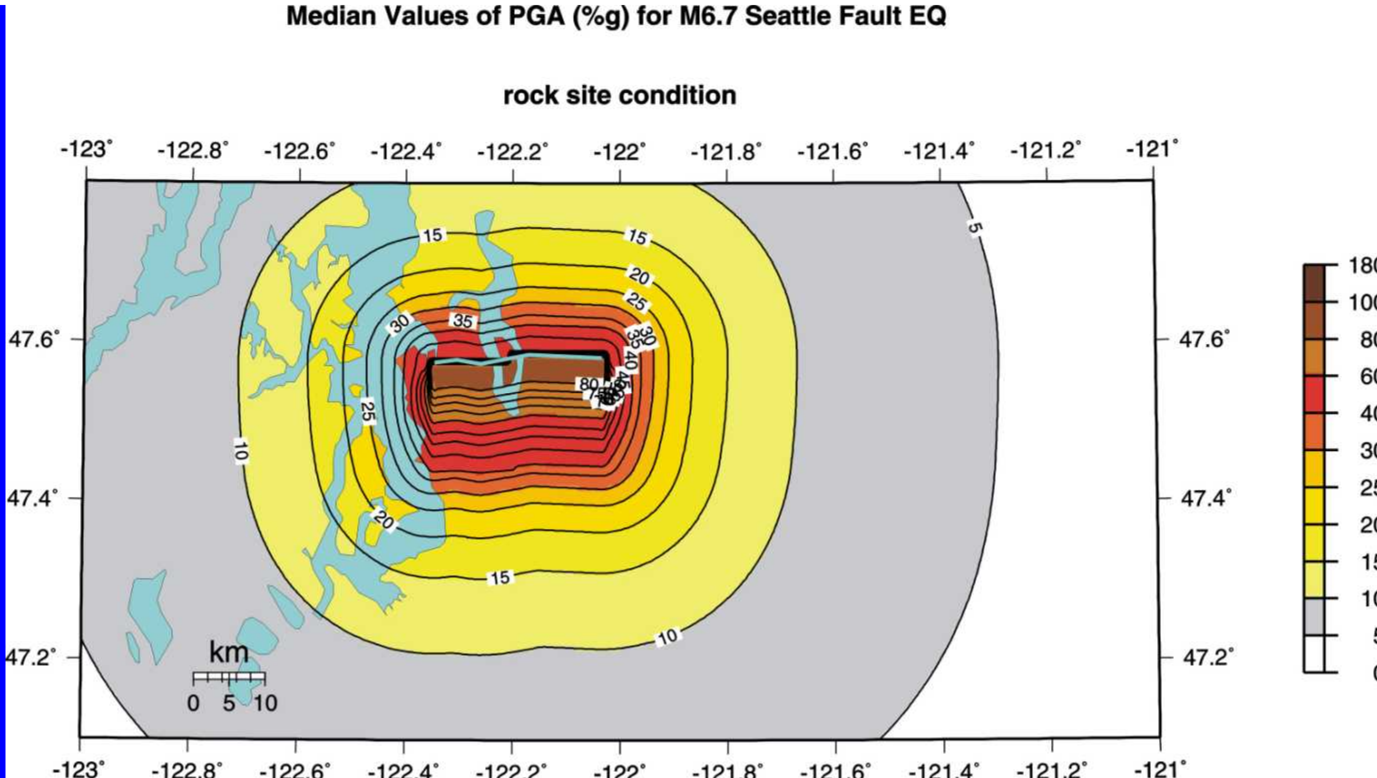


NGA relations

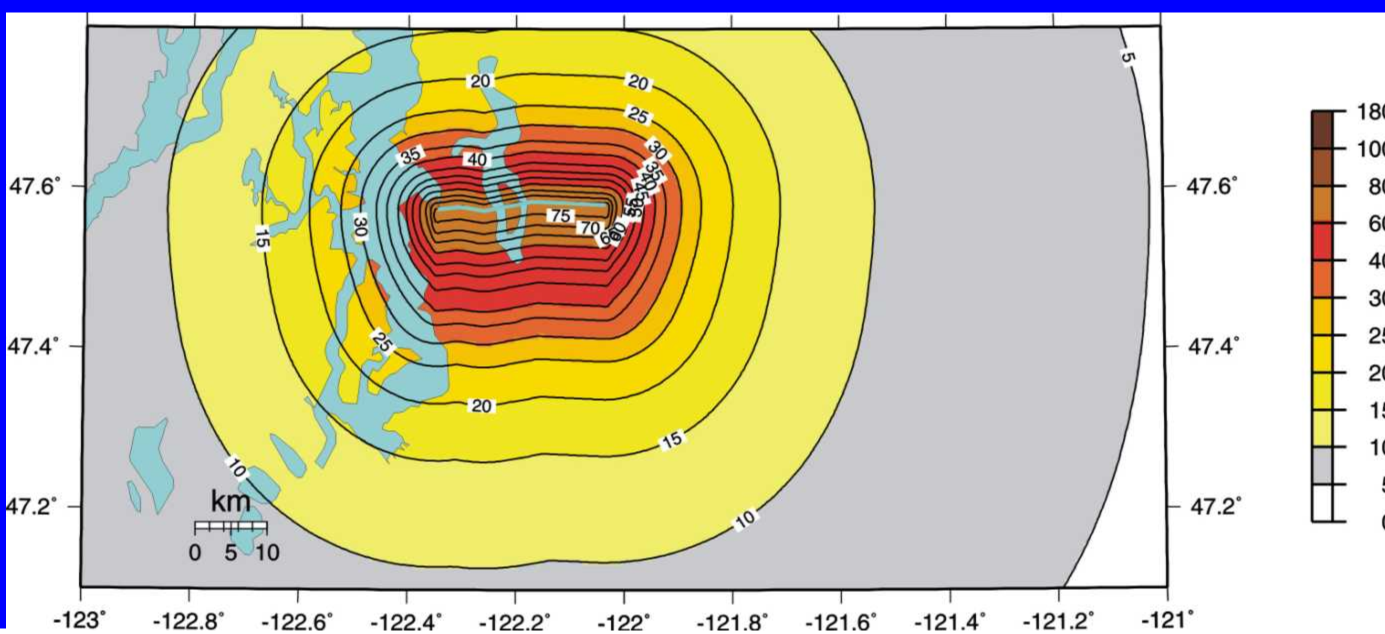
Issues for using NGA in the national maps

- Do we give full weight to NGA? Or part weight to attenuation relations used in 2002? Do we think that Chi-Chi, Kocaeli (Izmit) and Denali recordings may be biased?
- Depth to top of rupture is now a parameter. How do we implement in a logic tree?
- Epistemic uncertainty
- Do we still use Vs30=760 m/s, or go to 620 m/s?

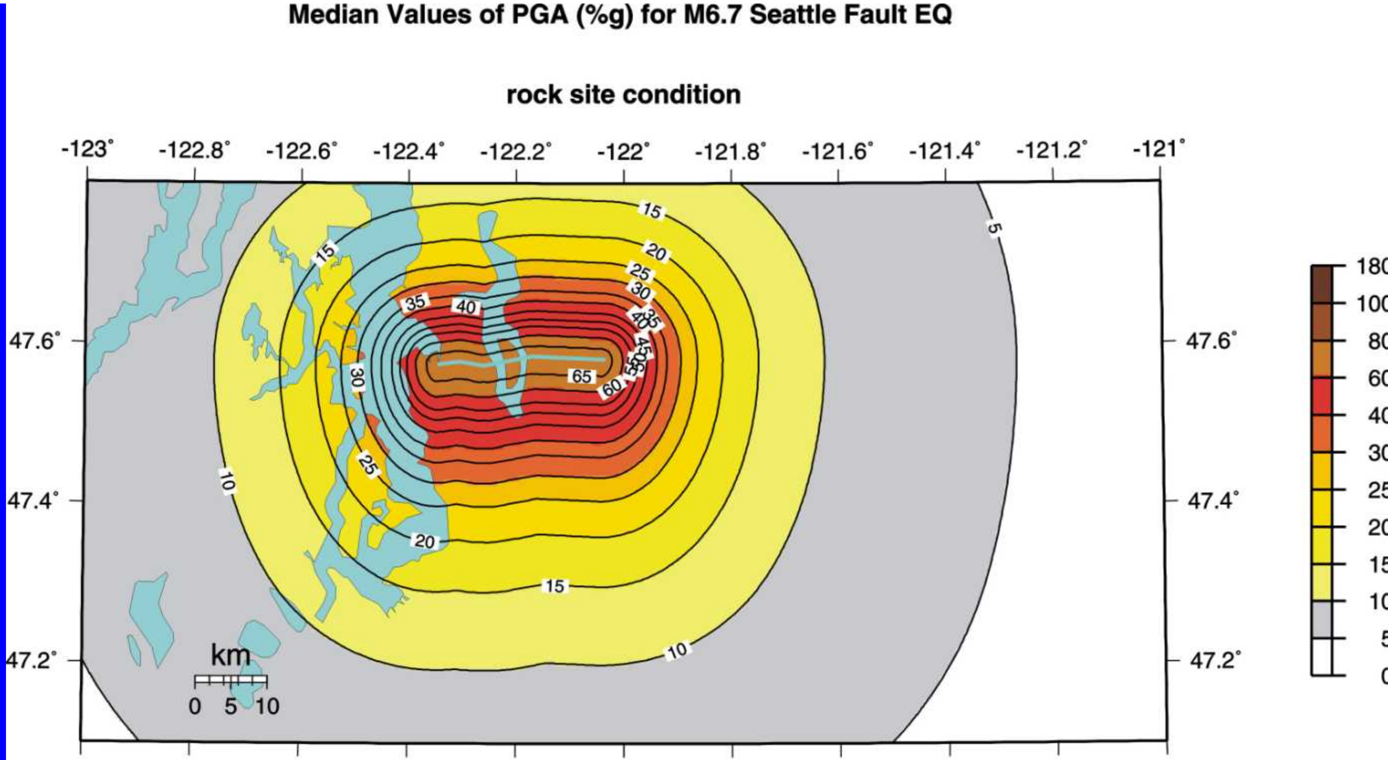
- New parameter: depth to top of rupture



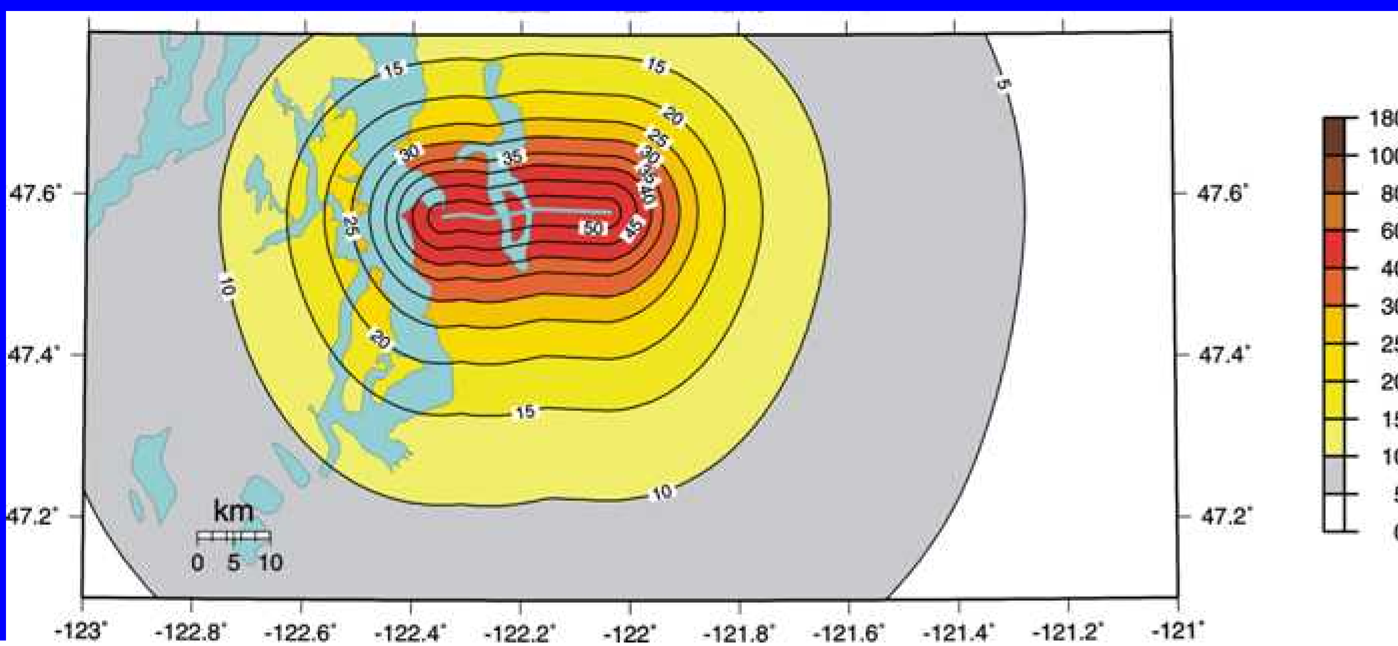
Campbell and Bozorgnia, NGA
Dtor= 0



Dtor= 5 km



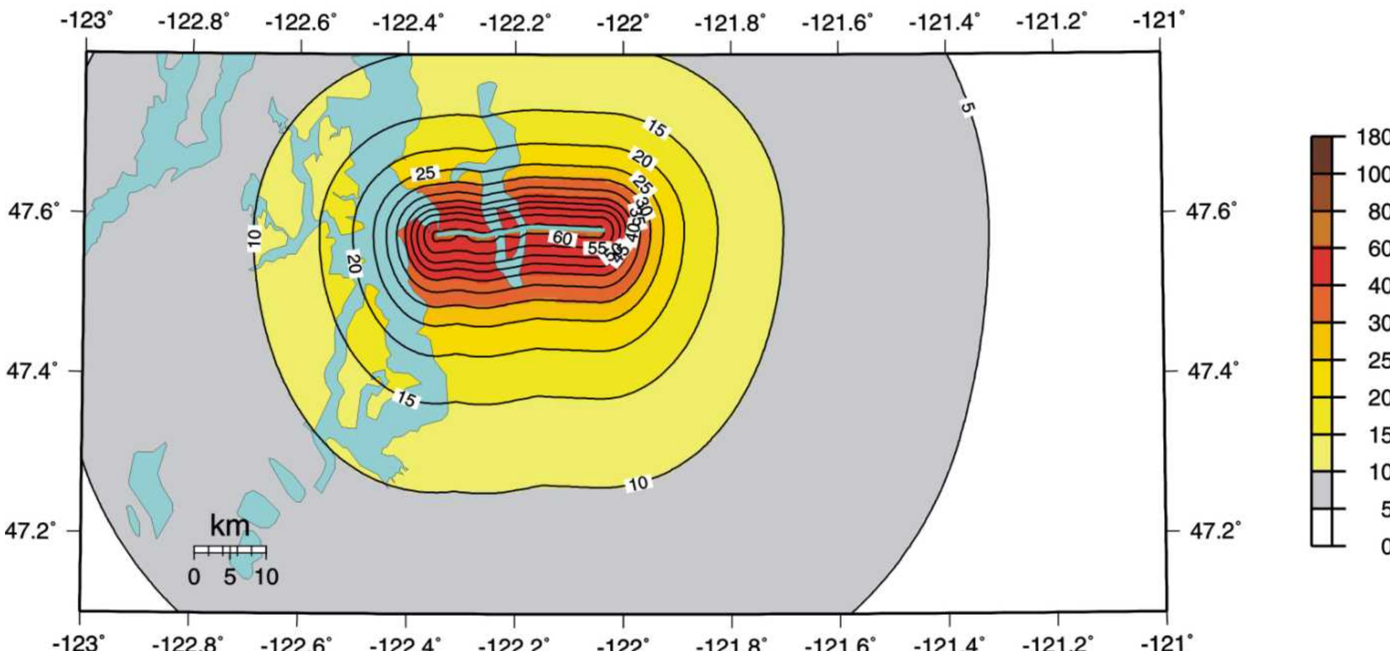
Abrahamson and Silva, NGA
Dtor= 0



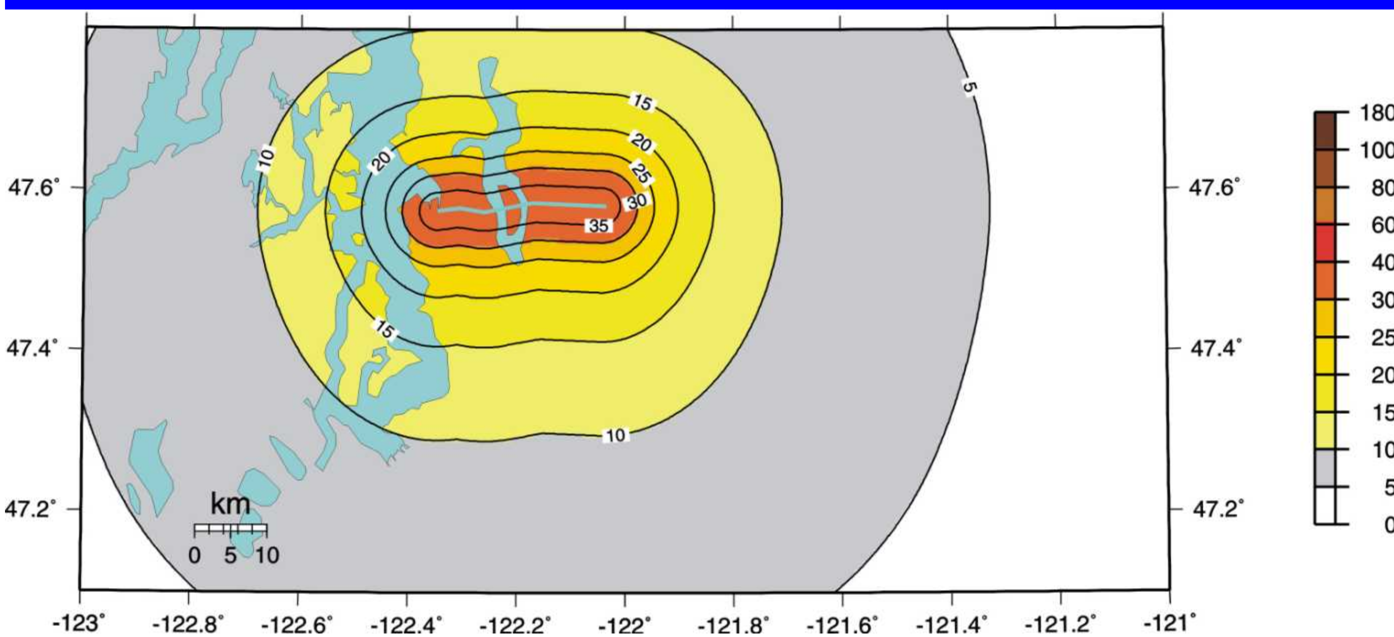
Dtor= 5 km

Median Values of 1 Hz S.A. (%g) for M6.7 Seattle Fault EQ

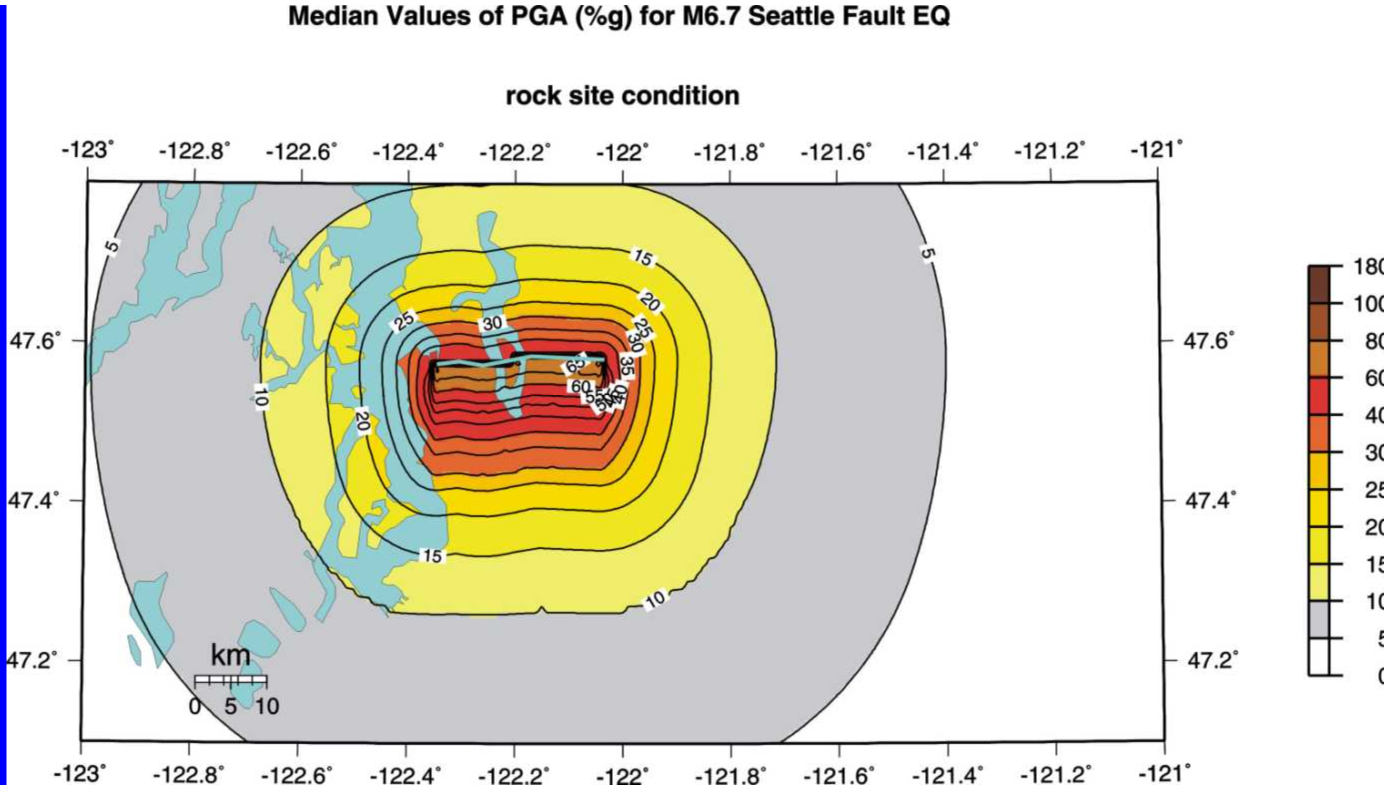
rock site condition



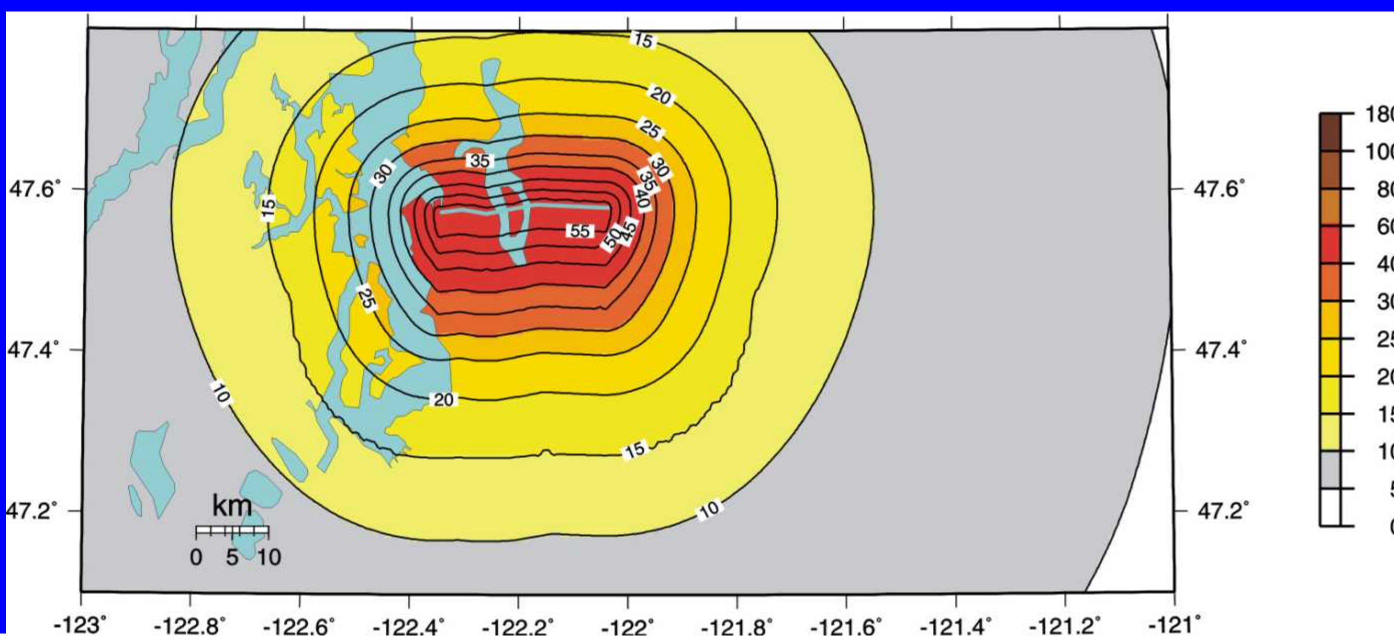
Abrahamson and Silva, NGA
Dtor= 0



Dtor= 5 km



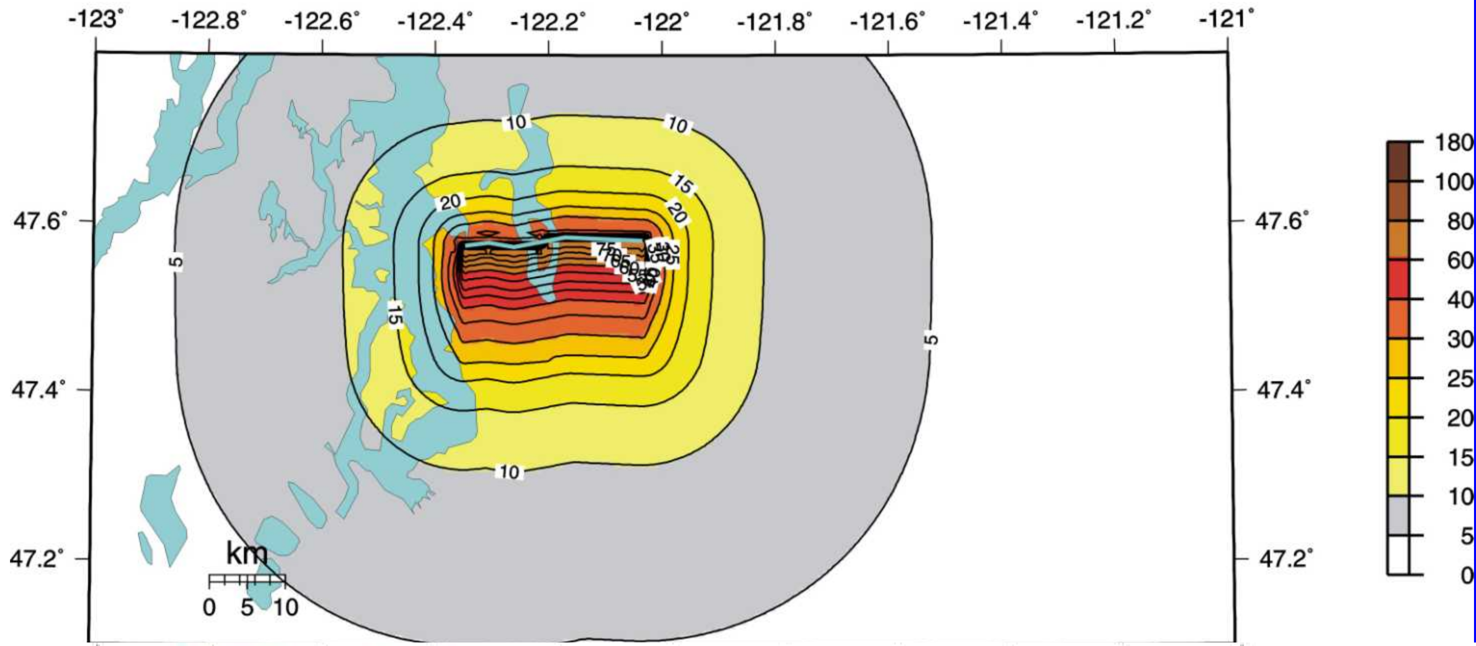
Chiou and Youngs NGA Dtor=0



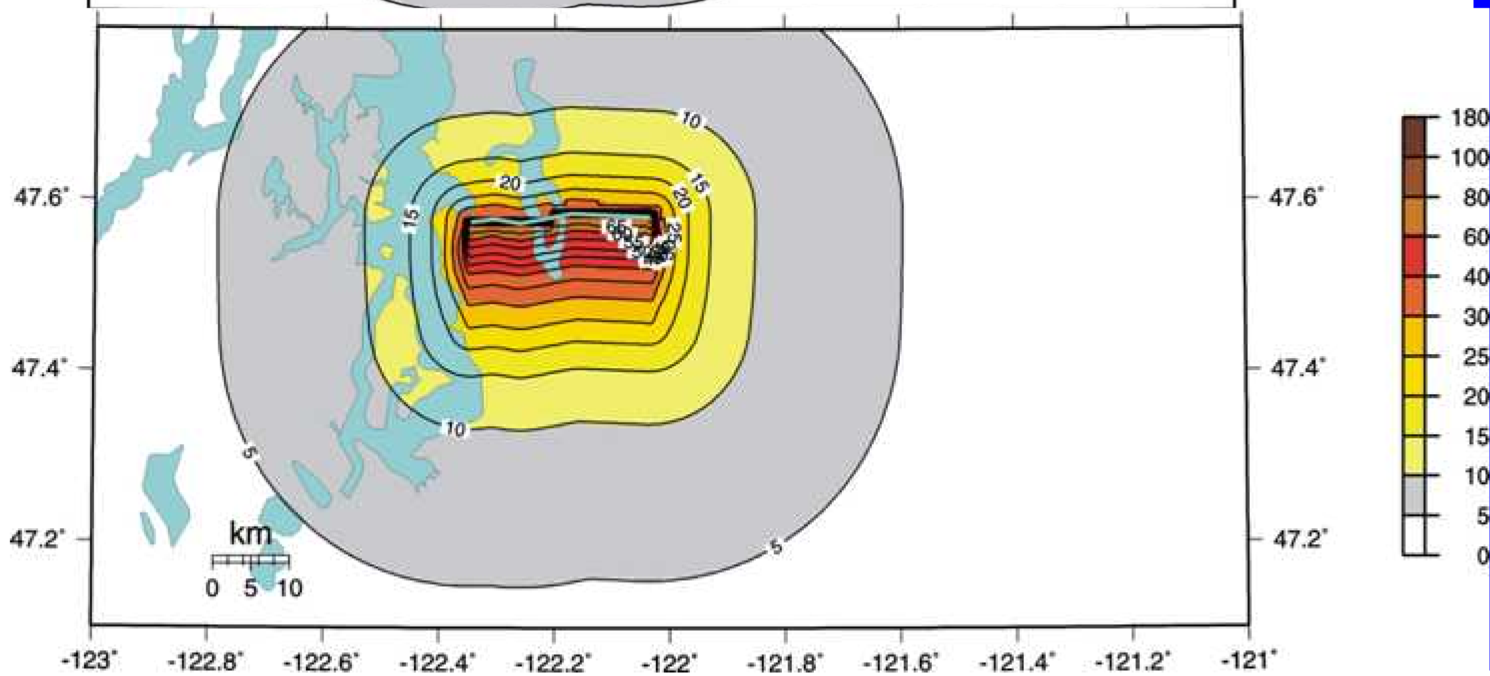
Dtor= 8 km

Median Values of 1 Hz S.A. (%g) for M6.7 Seattle Fault EQ

rock site condition

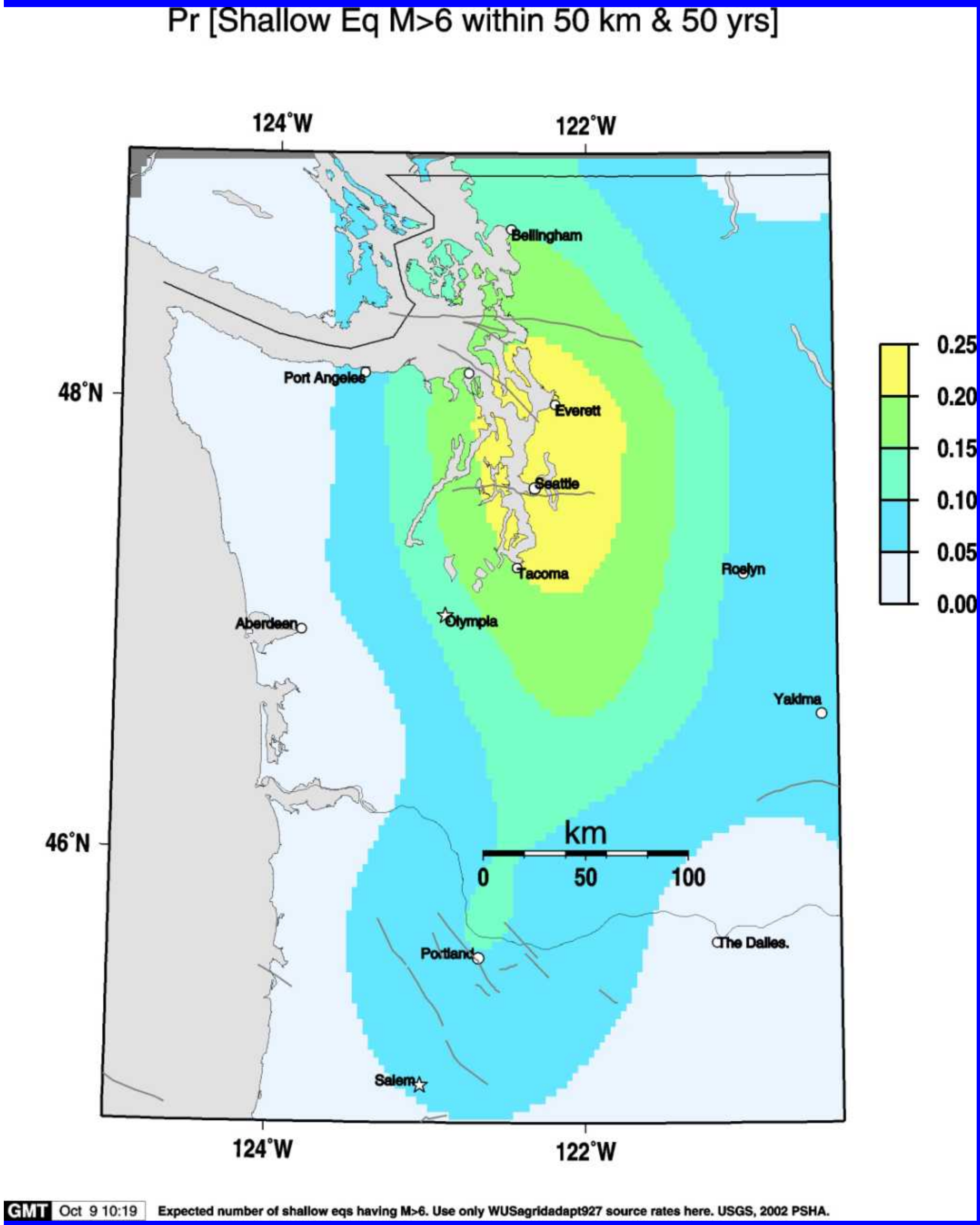


Campbell and Bozorgnia, NGA
Basin depth = 1 km



Campbell and Bozorgnia, 2003
Basin depth= 0

New Products



Earthquake probability maps

You enter lat, lon or zipcode time period, and magnitude

Outputs map of probability of earthquakes within 50 km and report for your specific site

eqhazmaps.usgs.gov
under custom mapping
and analysis tools

Probabilistic Seismic Hazard Maps for Seattle That Include 3D Sedimentary Basin Effects, Rupture Directivity, and Site Response

(Urban Seismic Hazard Maps for Seattle for 1 Hz S.A.)

A. Frankel, W. Stephenson,

D. Carver, R. Williams, J. Odum, and S. Rhea

USGS, Golden, CO

USGS science for a changing world

Why do we need 3D simulations?

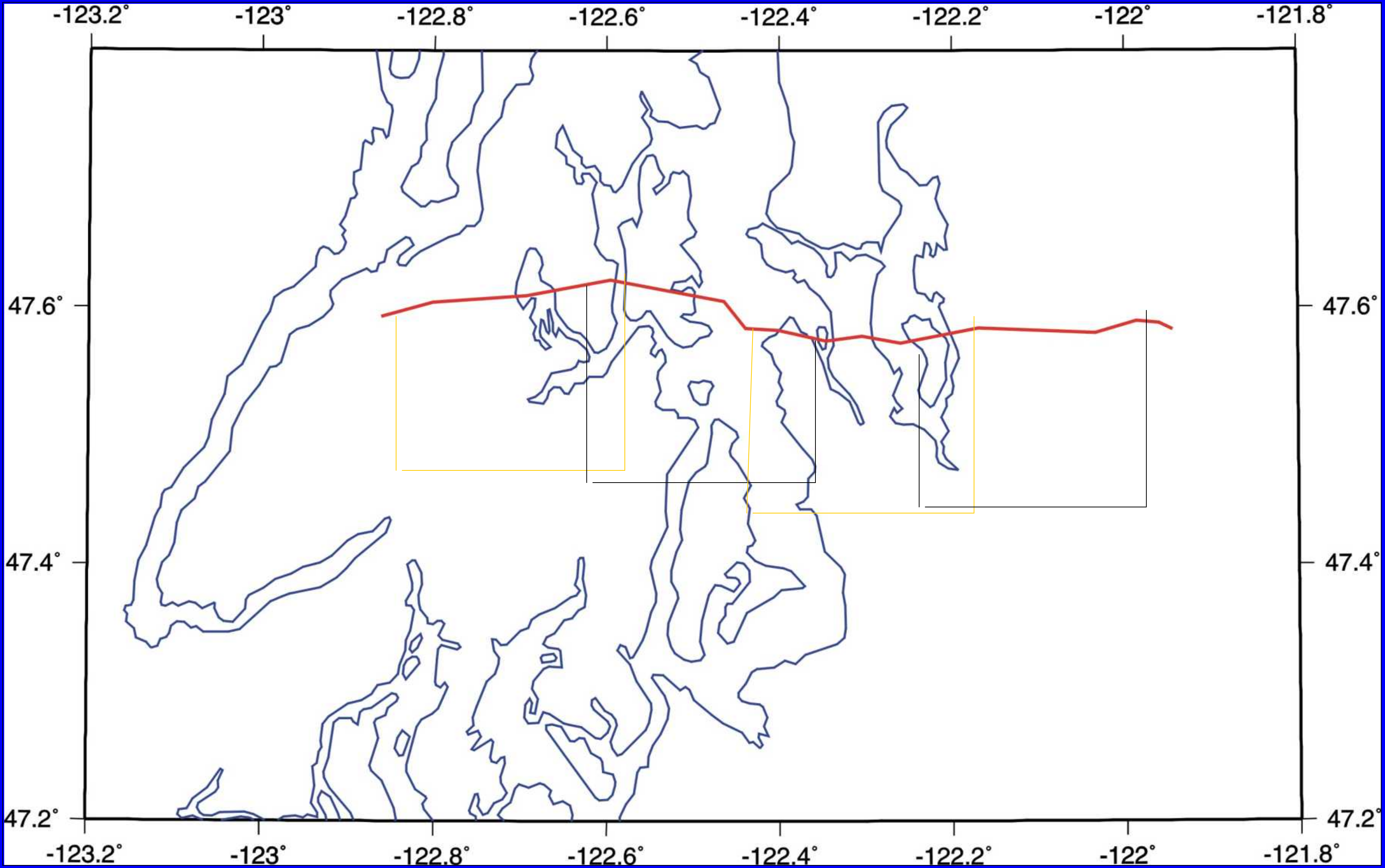
- Observations of basin surface waves in the Seattle basin for the Nisqually earthquake and other events: these surface waves account for much of the 1 Hz amplification at stiff soil sites in the Seattle basin
- Observation that the 1 Hz amplification at stiff soil sites in the Seattle basin varies with azimuth to the source

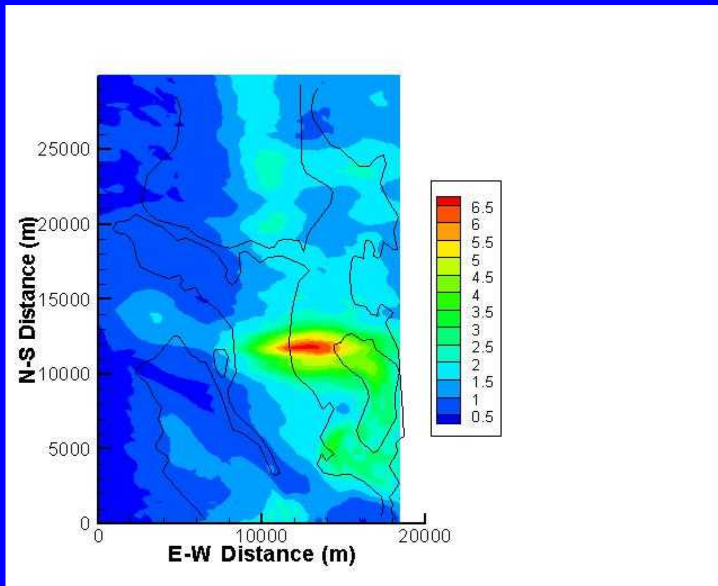
- We constructed 3D velocity model for Puget Sound region using results from seismic tomography, seismic reflection/refraction, gravity, borehole data
- Validated model up to 1 Hz by comparing synthetics and amplification patterns from 3D simulations with observations from 5 earthquakes, including Nisqually earthquake

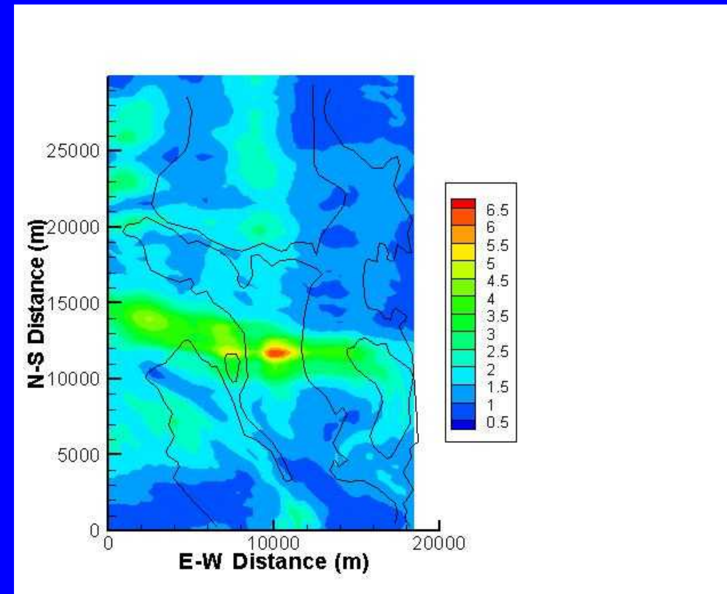
3D simulations used in maps

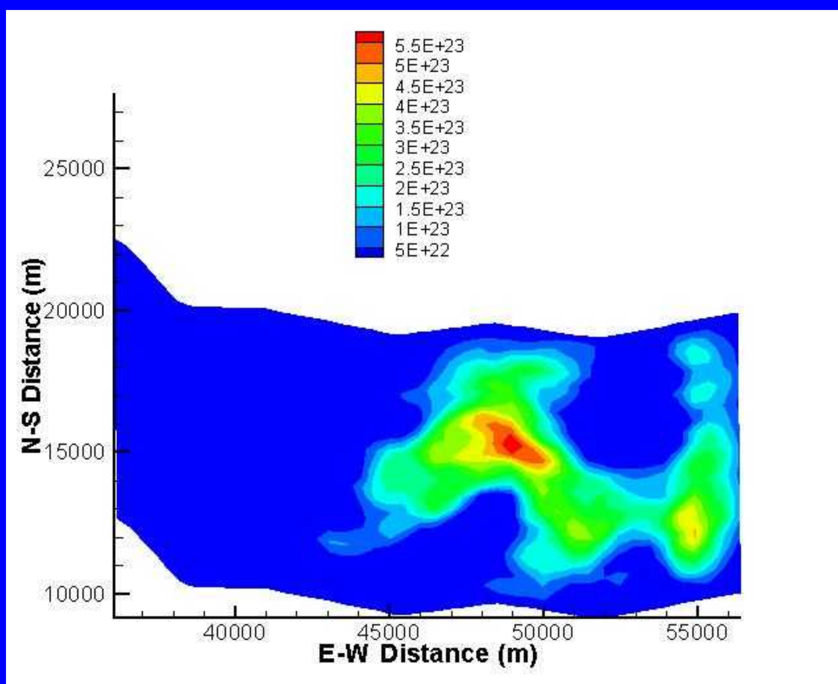
- 315 simulations for earthquakes in Seattle fault zone (M6.5-M7.2)
- 9 simulations for earthquakes on South Whidbey Island fault
- 3 simulations for point sources on Cascadia subduction zone
- 16 simulations for shallow earthquakes: 8 azimuths and two depths (5 and 15 km)
- 8 simulations for deep earthquakes: 8 azimuths

Float rupture zones along fault trace, do nine 3D simulation for each rupture

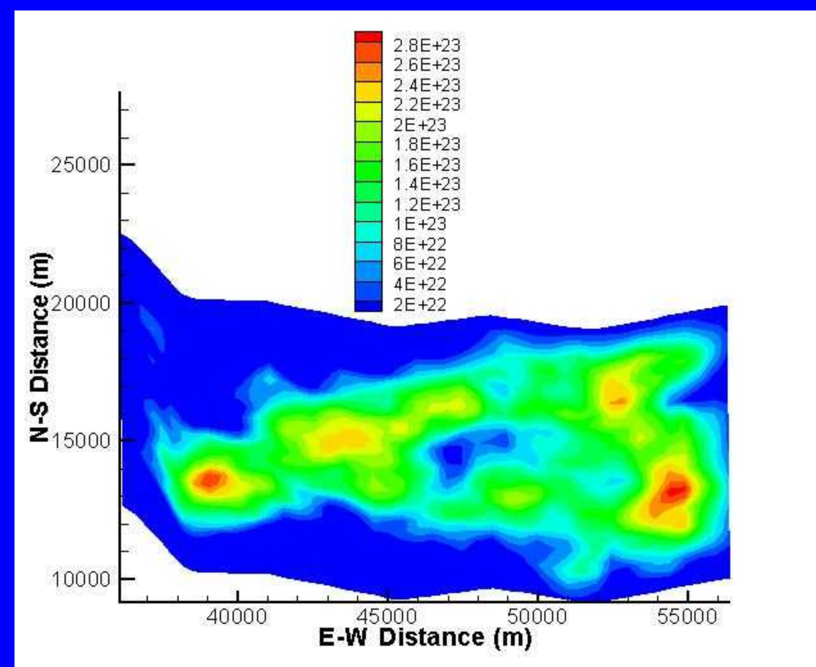






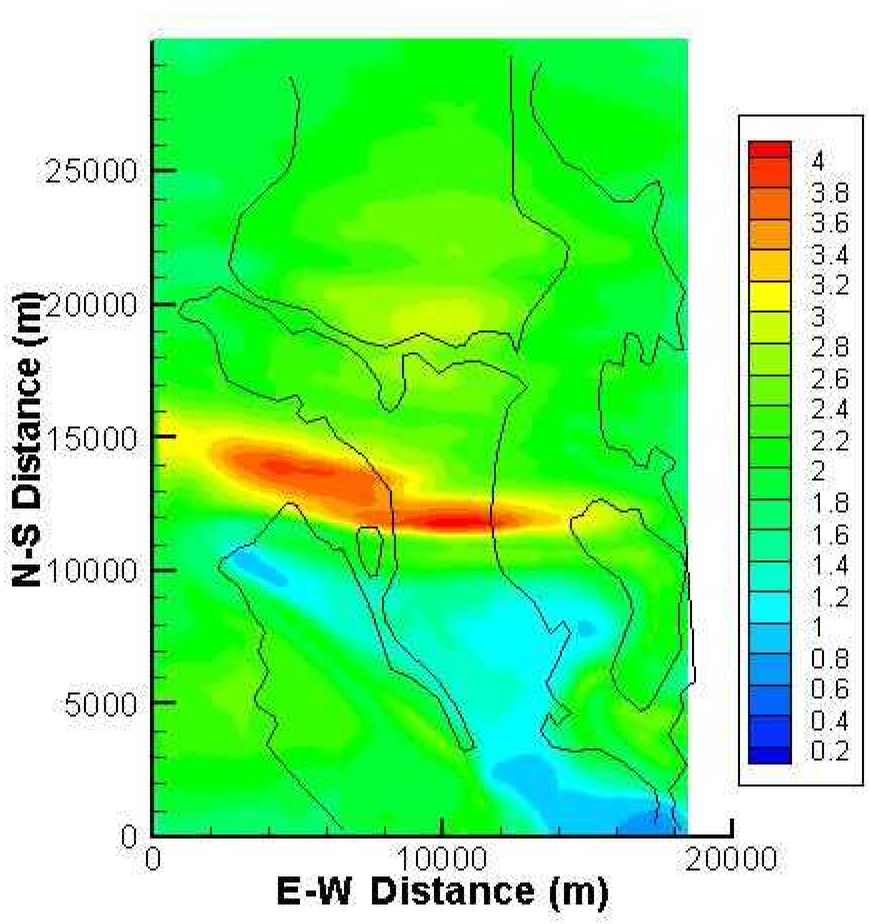


rupN14a



rupN14g

geometrical average of amplification from 315 Seattle fault earthquake simulations



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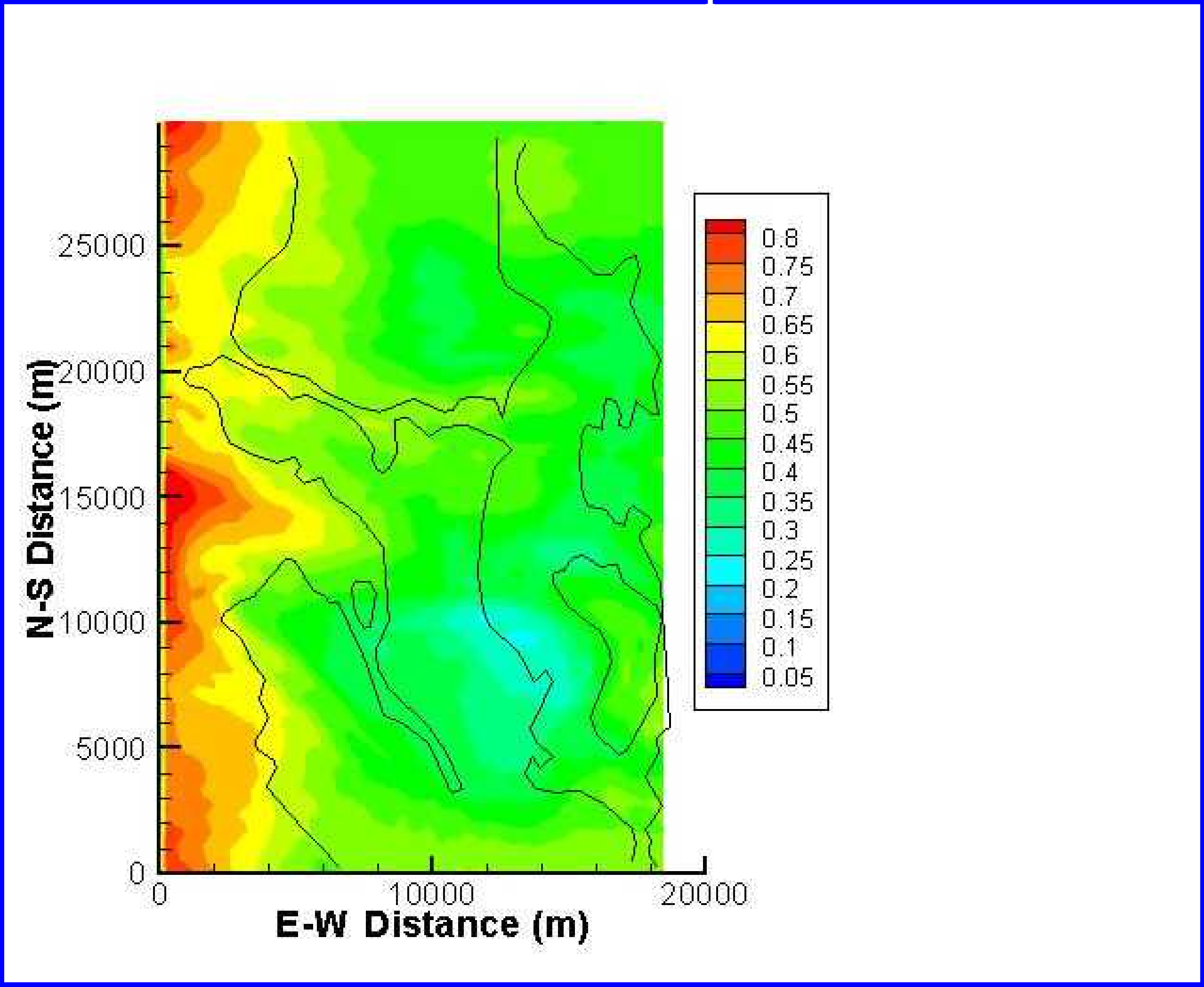
RMS of amplitude variation (ln units) from 315 Seattle fault earthquake simulations



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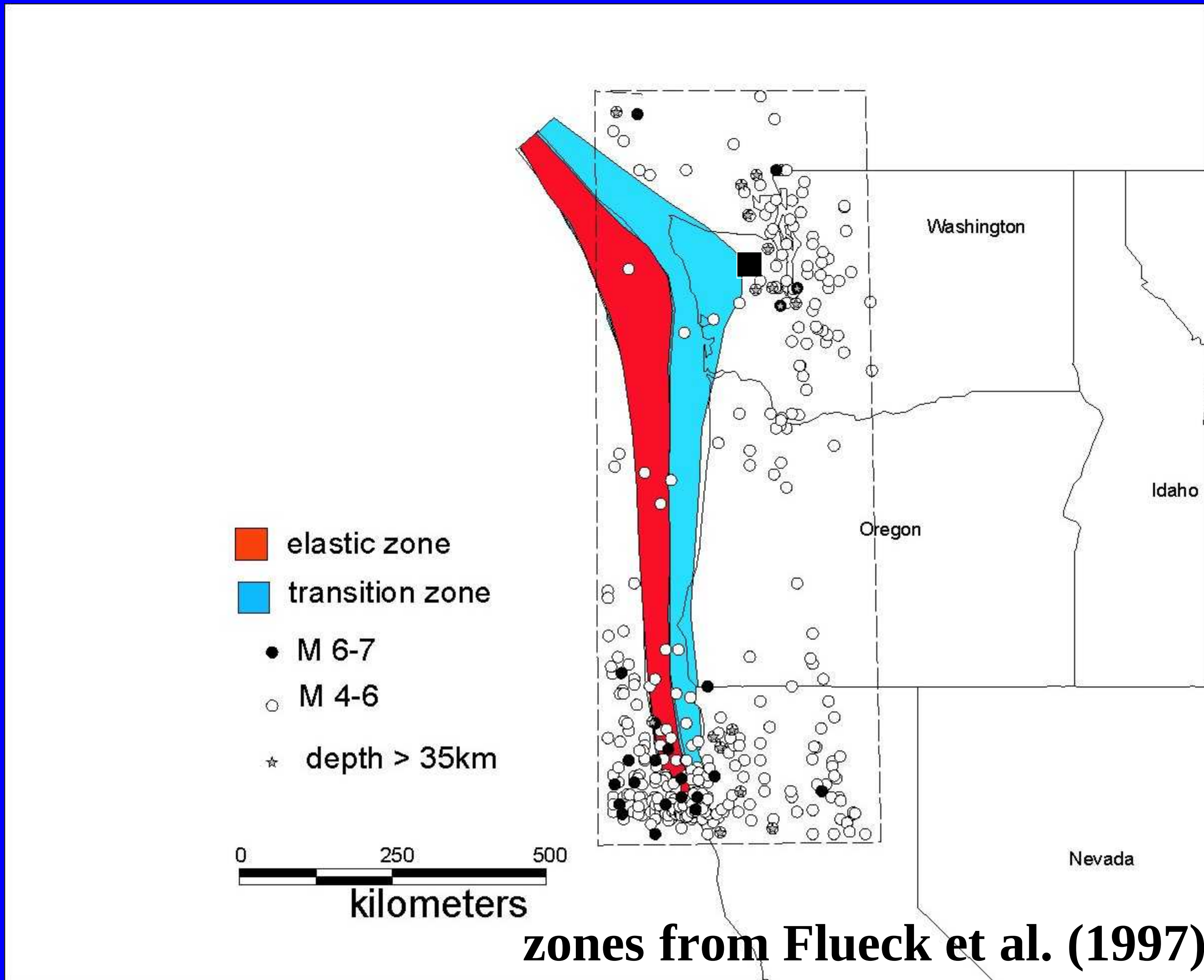
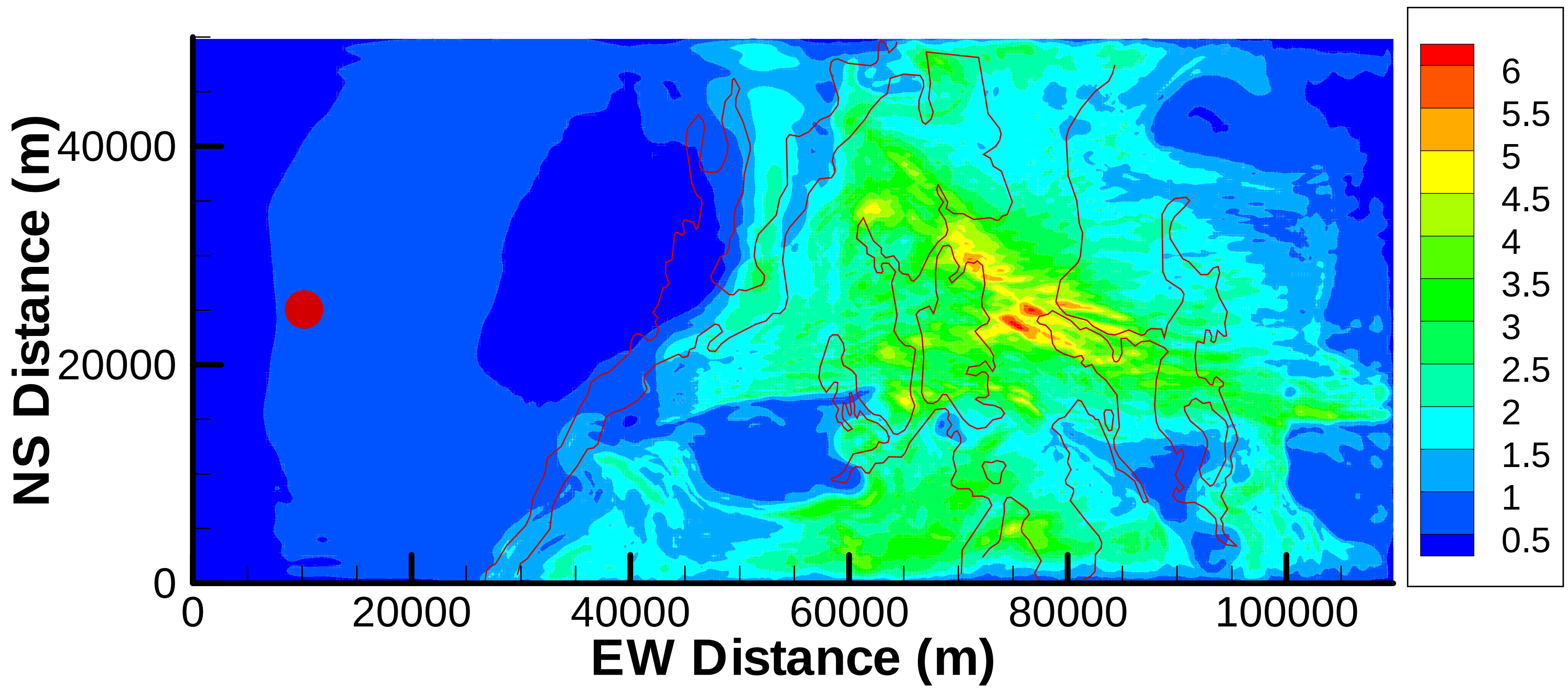
science for a changing world

Possible configurations for rupture zone of great Cascadia Earthquakes

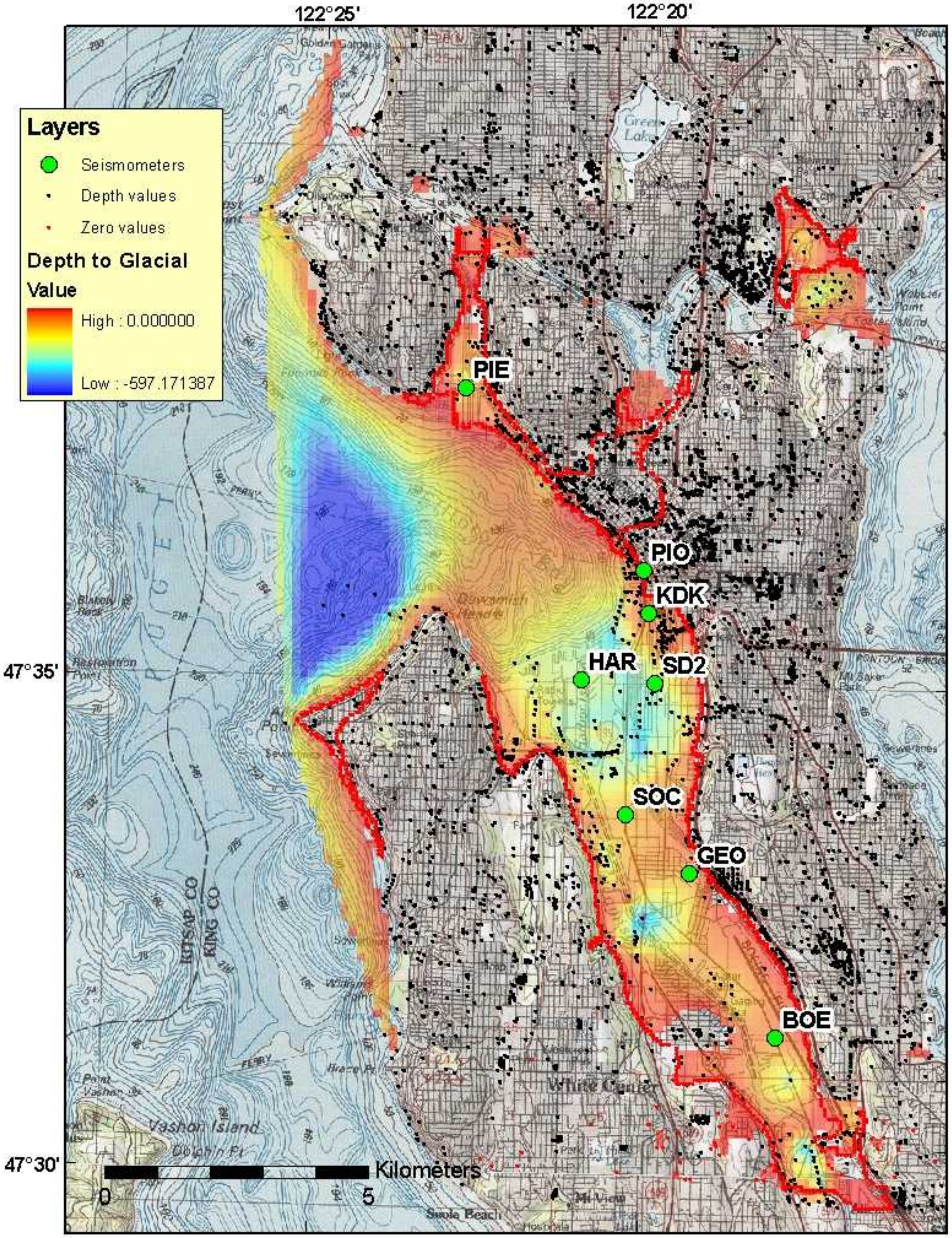


zones from Flueck et al. (1997)

Figure from Petersen et al. (2002)



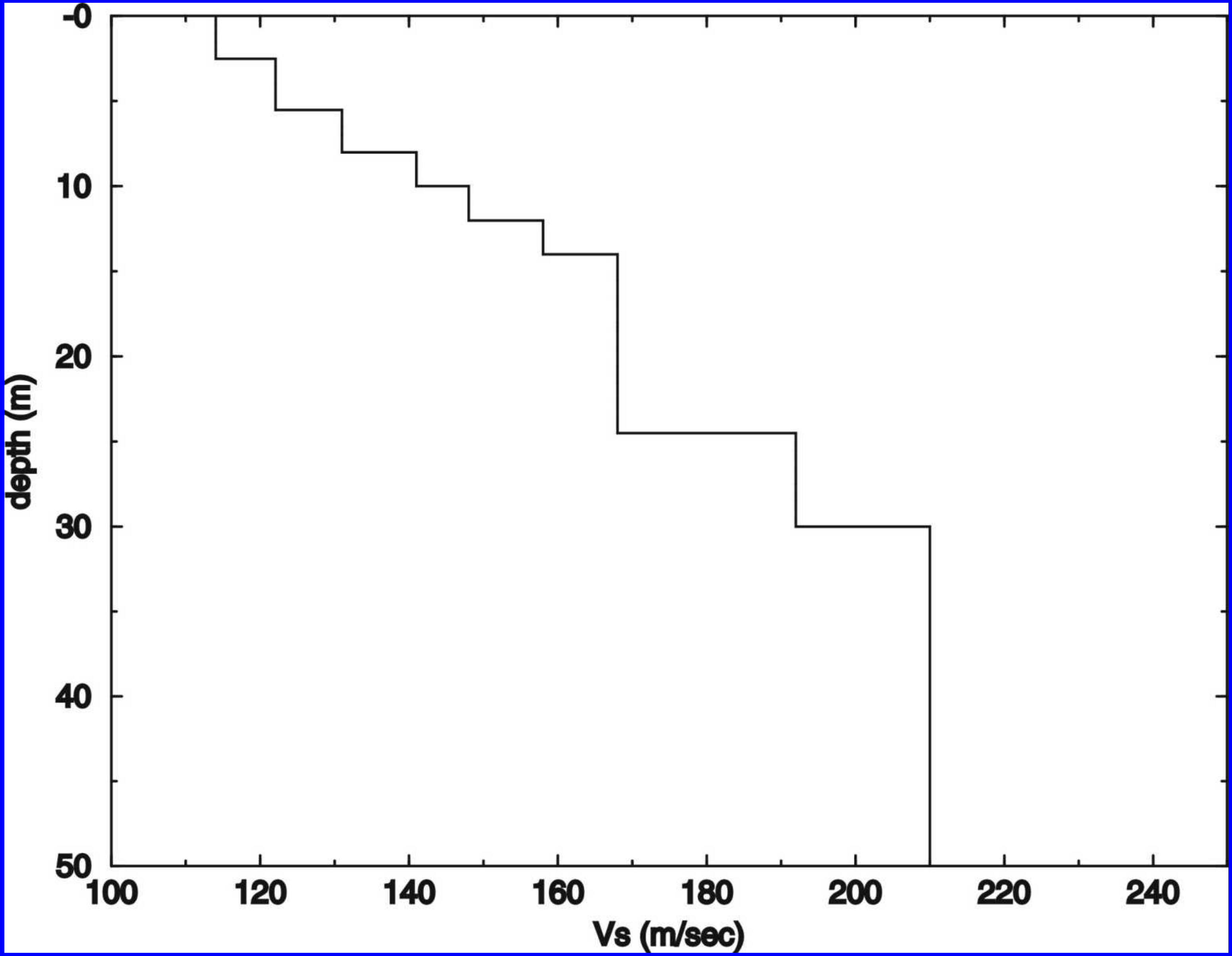
1 Hz amplification relative to local rock sites, for point source on Cascadia subduction zone (red dot)



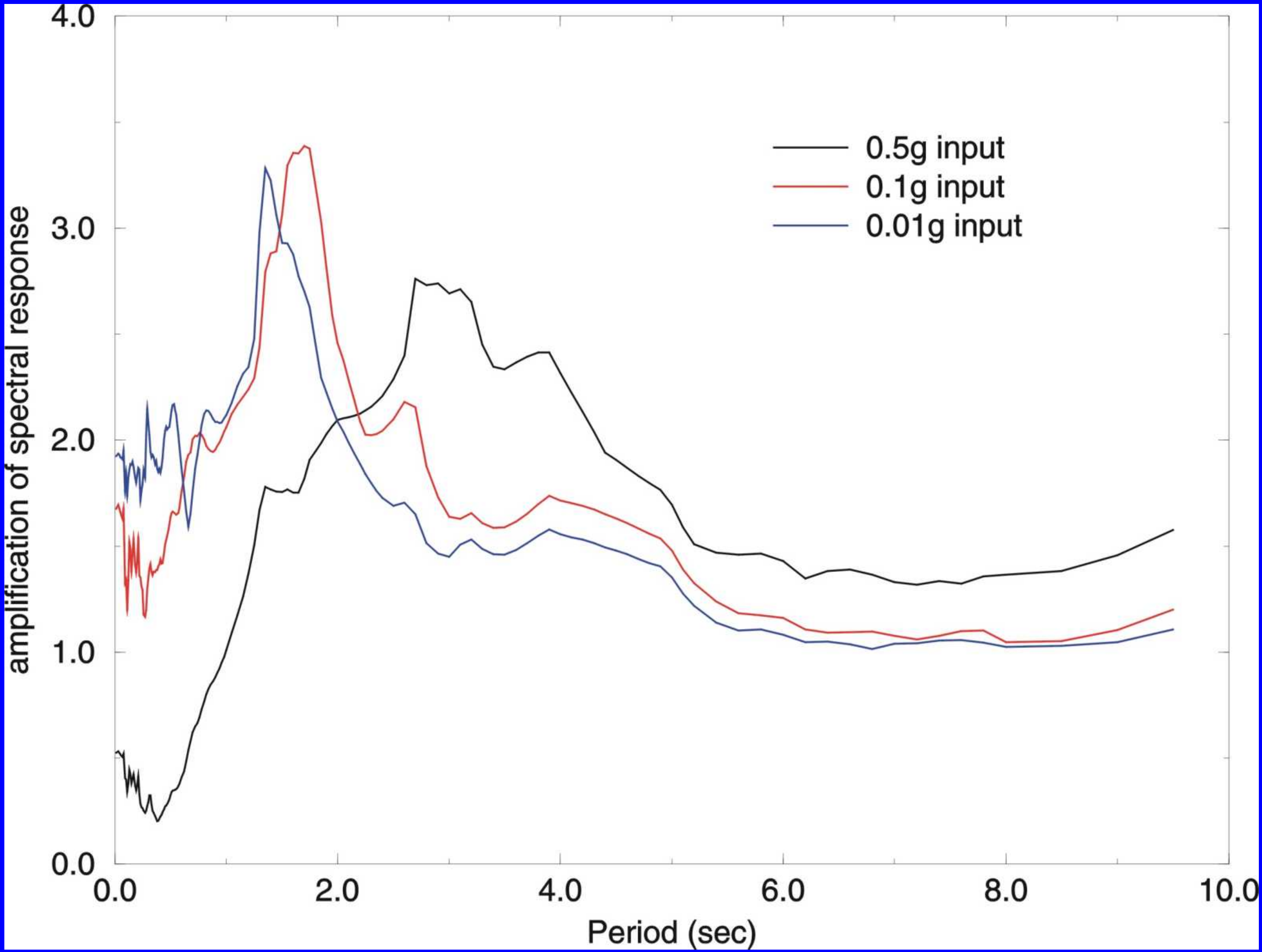
Map of thickness of fill and Holocene alluvium (ft) derived from fitting borehole data (dots) compiled by K. Troost and D. Booth (UW)

Figure provided by S. Rhea

Average Vs profile for fill sites, determined from refraction and borehole studies

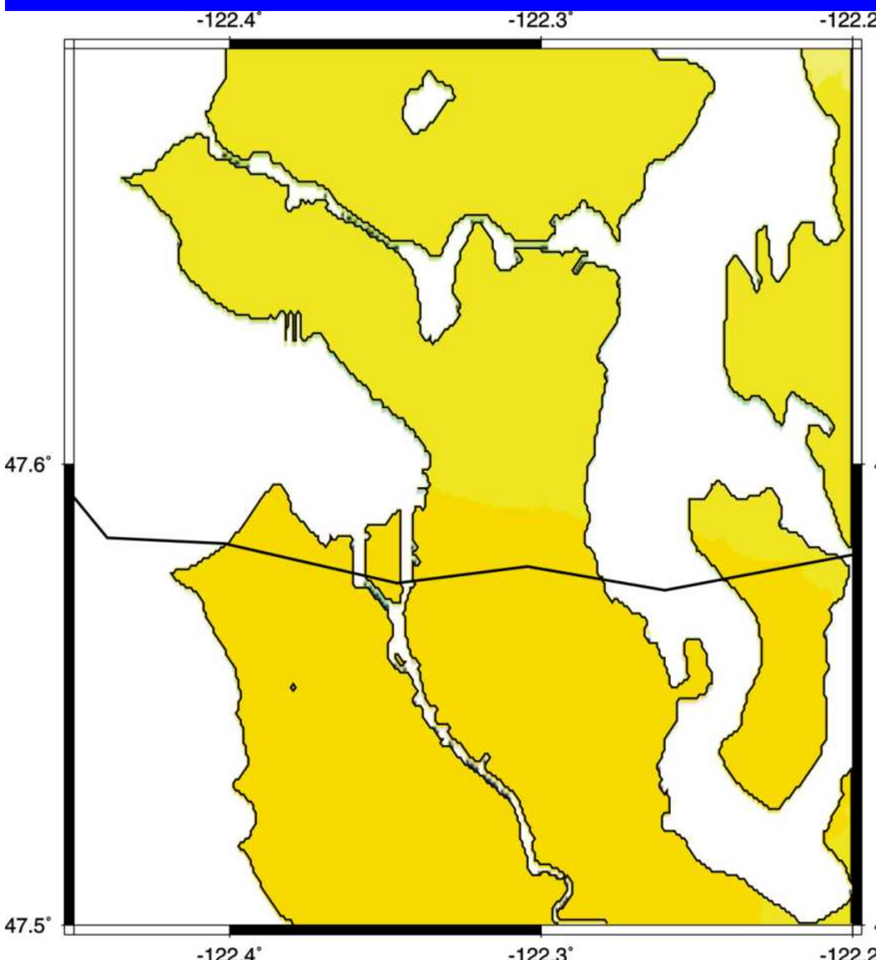


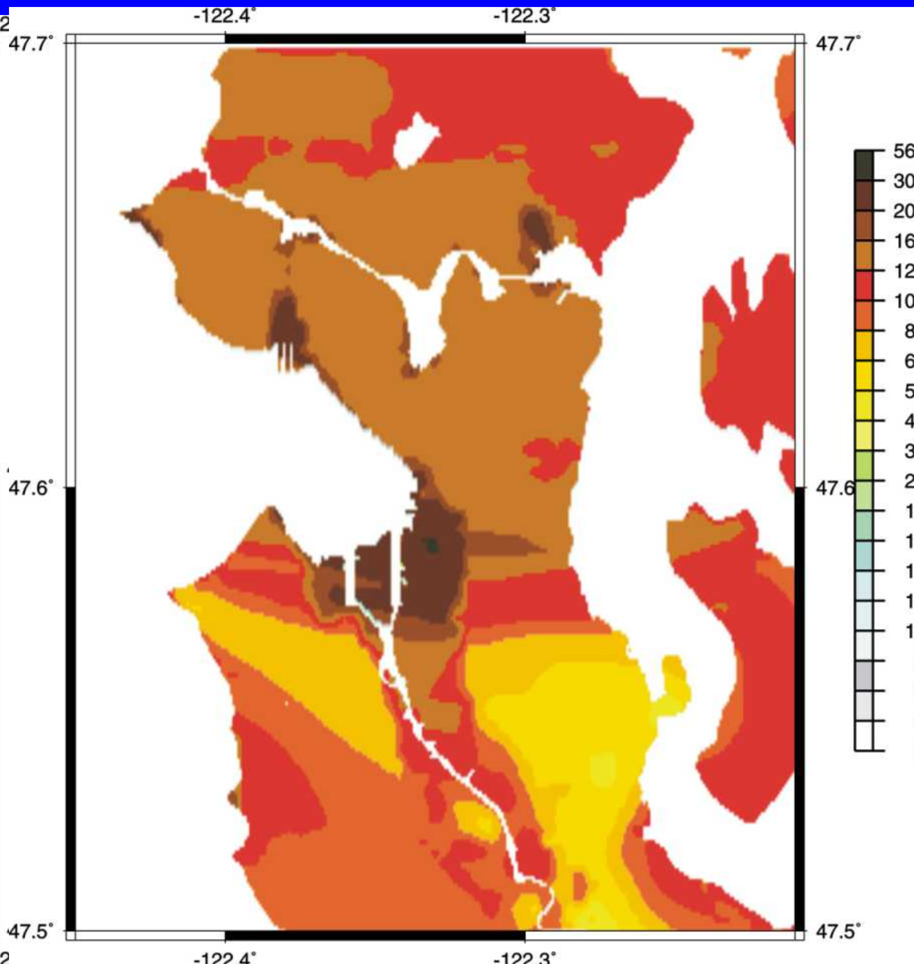
Amplification from Shake runs for inferred Vs profile at Harbor Island site



USGS
science for a changing world

1 Hz S.A. (%g) with 2% P.E. in 50 years





2002 national seismic Hazard maps

With 3D basin effects, site response and rupture directivity

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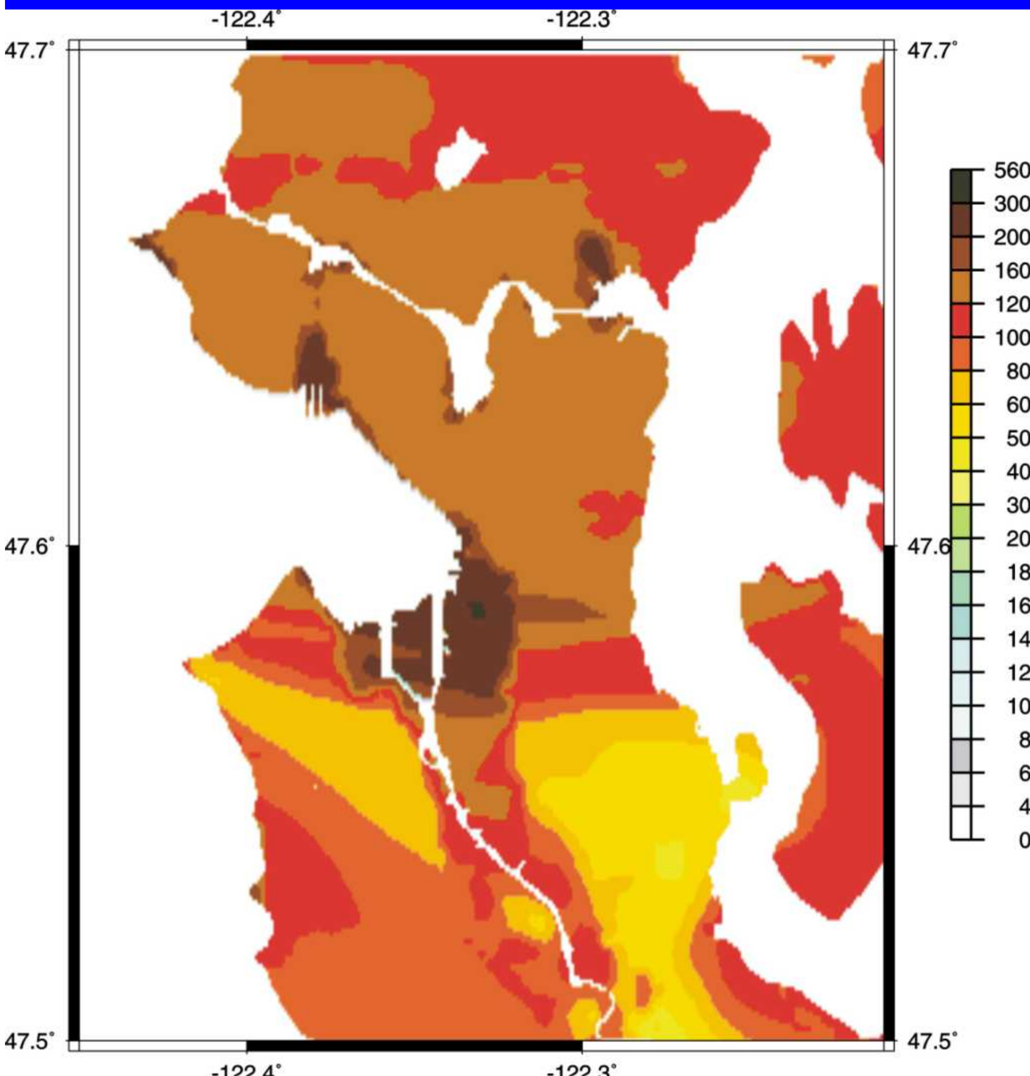
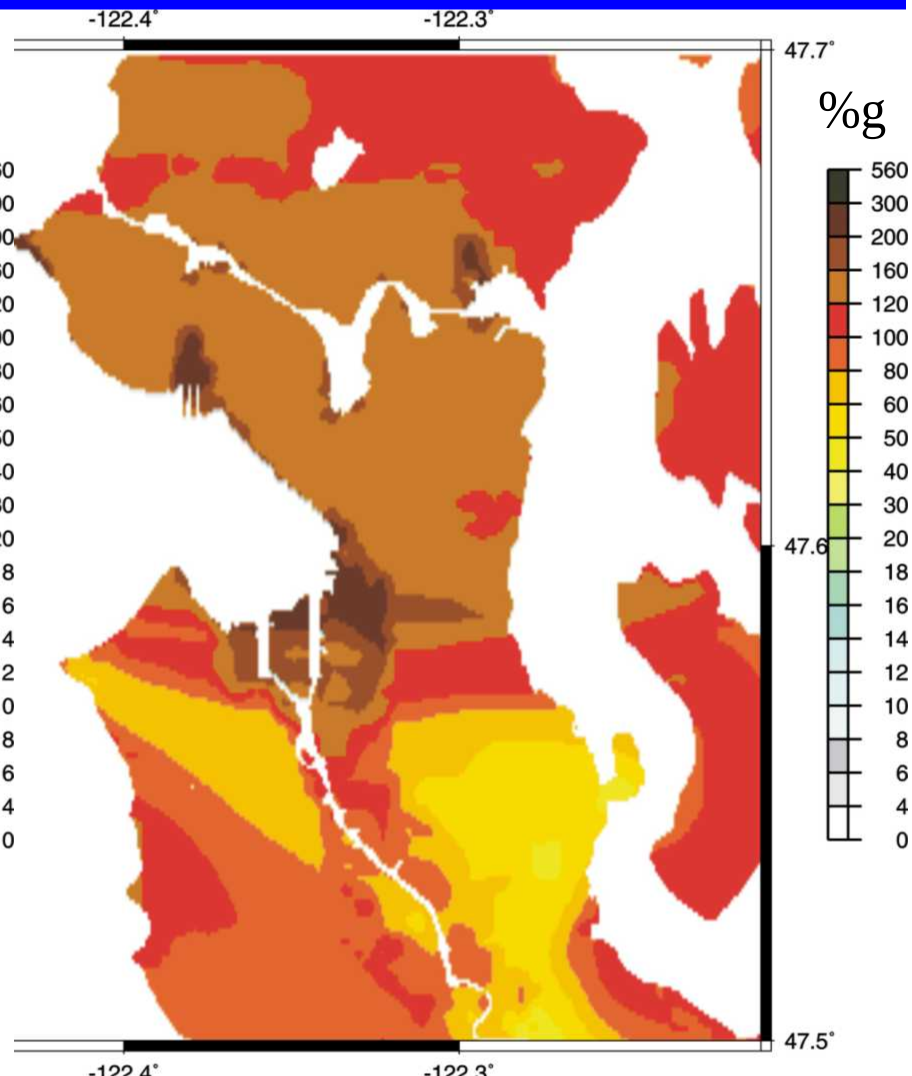
1 Hz spectral acceleration with 2% probability of exceedance in 50 years



Using 3D sims. +Vs30 and NEHRP amp. factors



Using 3D sims. +Vs profiles and Shake

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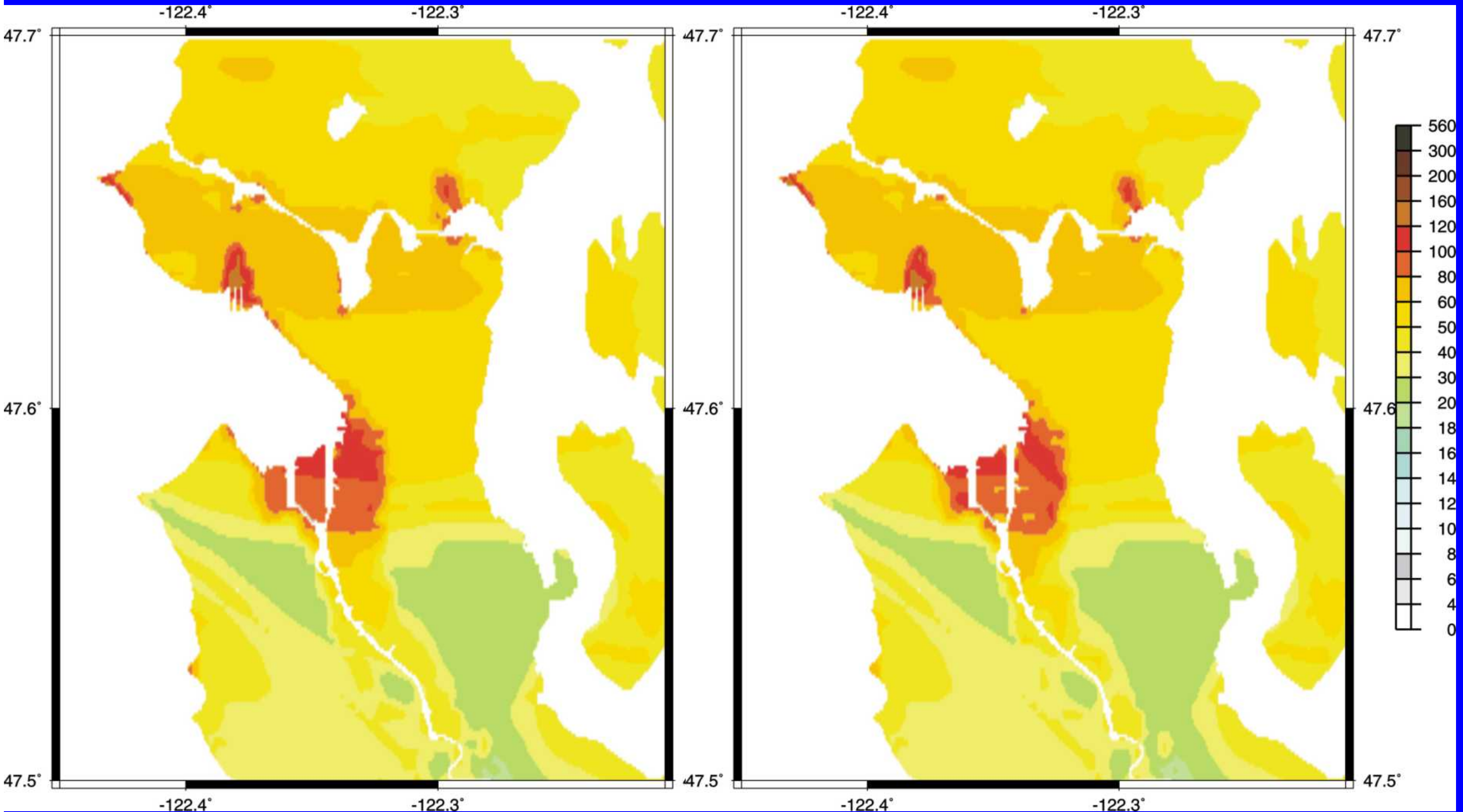
1 Hz S.A. (%g) with 10% PE in 50 years



Using 3D sims + Vs30 and NEHRP amp. factors

Using 3D sims + Vs profiles and Shake

Most hazardous places

1 Hz, 10 story buildings

- Soft soils
- Sedimentary basins
- Basin edges

5 Hz, 2 story buildings

- Hanging wall of thrust faults
- Basin edges

Future work

- Make Seattle hazard maps for 5 Hz S.A., using Vs30 and NGA relations (+ 2D simulations?)

- Make urban seismic hazard maps for Portland

- Maps for other communities?