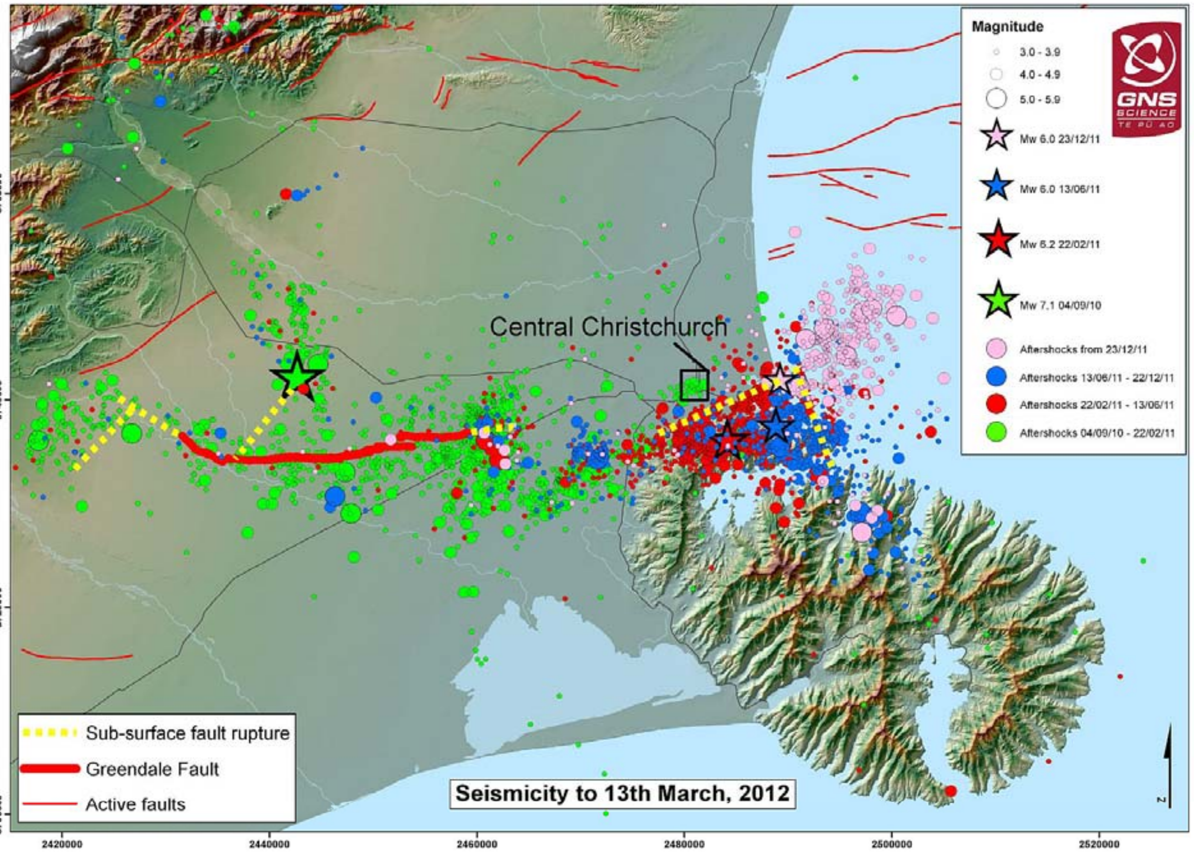
Comparisons of Darfield and Christchurch Ground Motions with NGA-W1 GMPEs

David M. Boore

Workshop on Update of Pacific Northwest Portion of the U.S. National Seismic Hazard Maps (NSHMs)

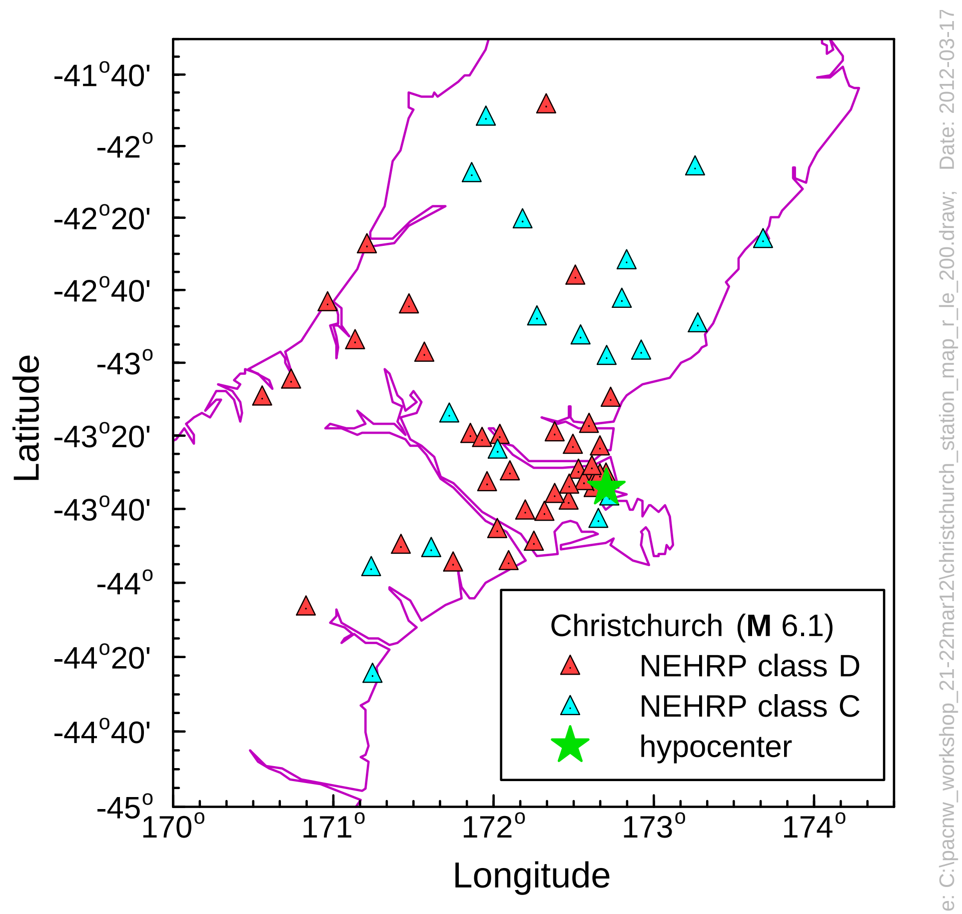
March 21-22, University of Washington, Seattle



(http://www.geonet.org.nz/canterbury-quakes/)

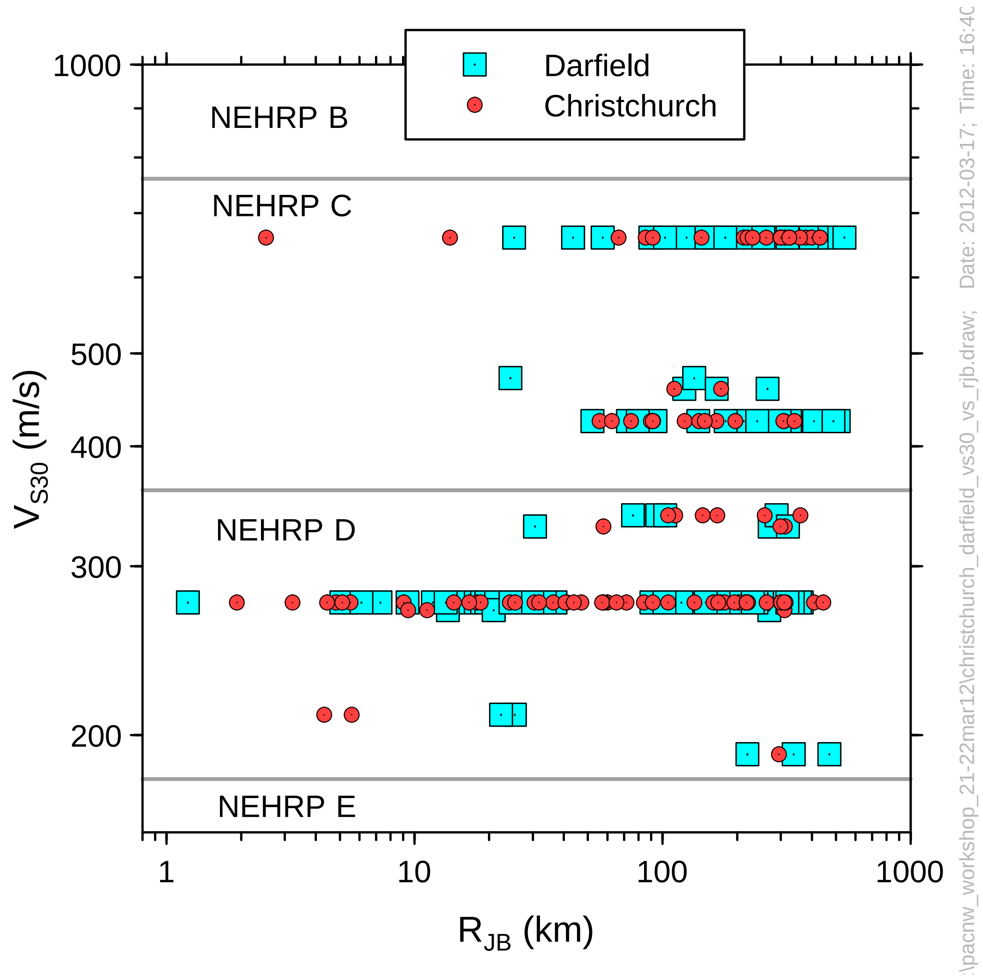
Stations for which Rjb<= 200 km

Class C sites at greater distance may have smaller depth of sediments than those near Christchurch



Most class C sites to the north

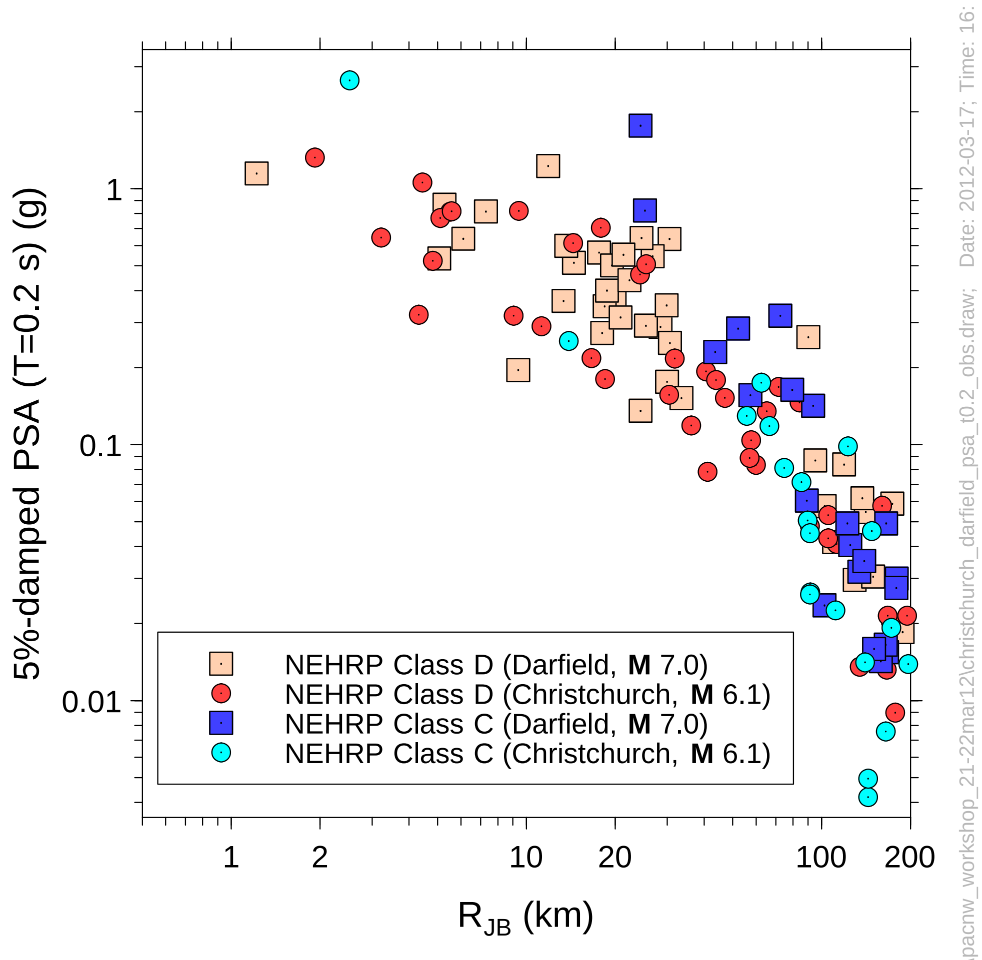
- Many sites with Vs30 = 275 and 660 m/s because values were estimated, not measured
- Distributions of Vs30 similar for both events
- Most records with R<100 km are from class D sites



Note: Some sites classified as “E” by Bradley & Cuprinovski (2011)

Comparison of Darfield and Christchurch Ground Motions

- Motions from both events at close distances are comparable
- Apparently no or small site effect (but note difference in spatial locations for different class sites, so source effects could compensate for site effects)
- Nonlinear soil response could have reduced motions for the larger event

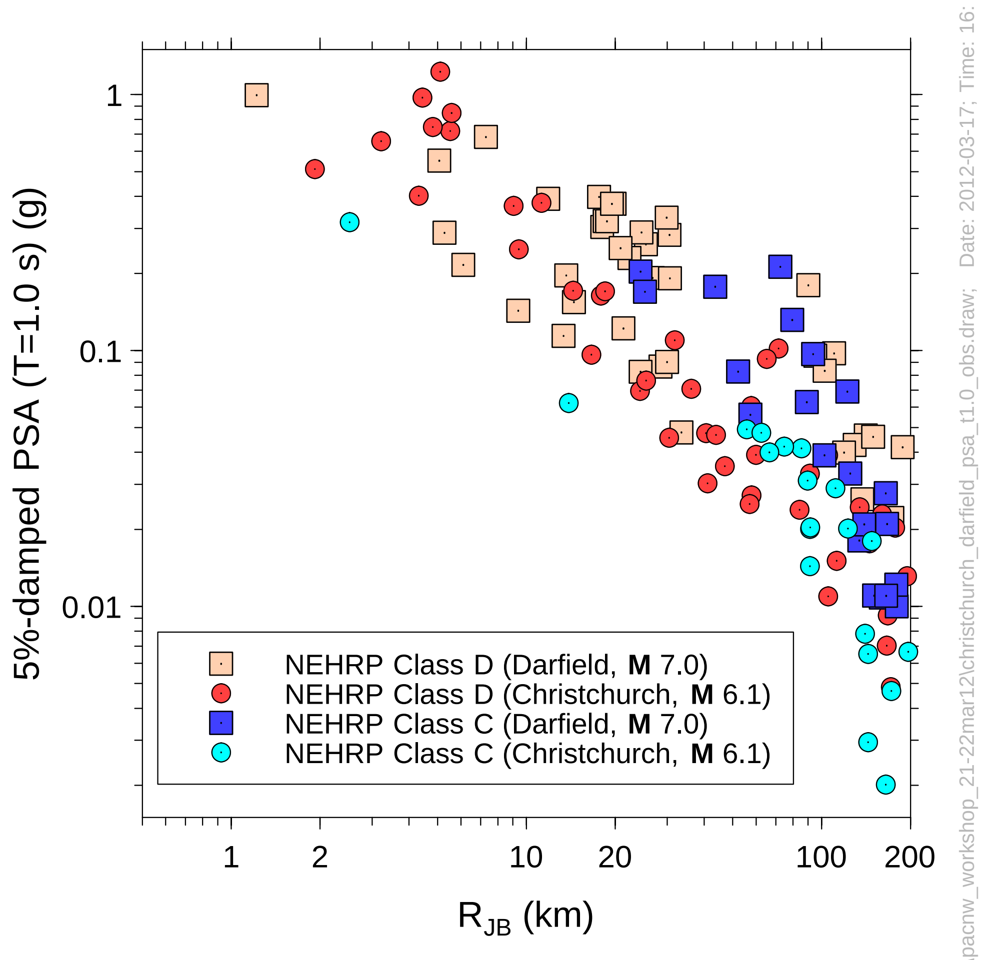


Observed RotD50 reduced to GMRotI50 using factors from Boore (2010); maximum effect is 4% at T=5 s.

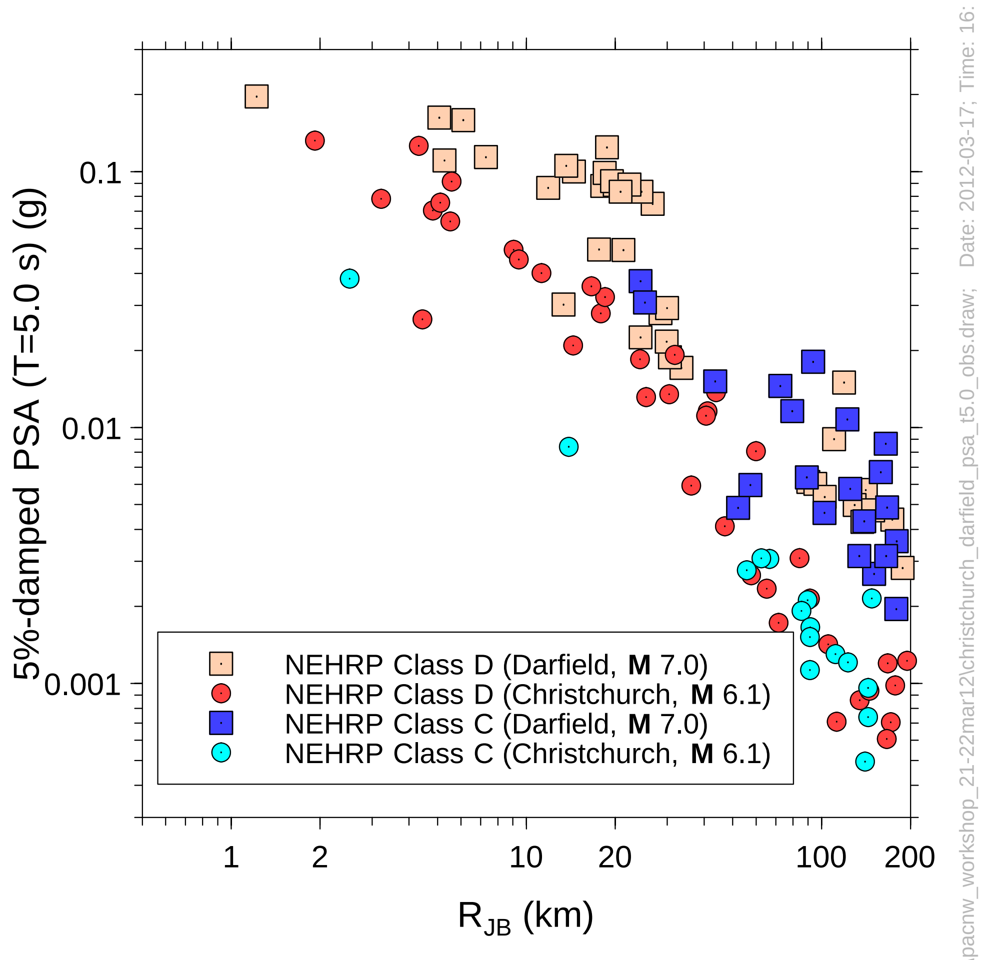
In this and subsequent comparisons, the Y-axis spans three orders of magnitude.

Concentrate on H components, as the 2008 NGA GMPEs were only for H.

- Christchurch (**M** 6.1) class D motions comparable or even larger than Darfield (**M** 7.0) at close distances
- Darfield class C motions greater than Christchurch motions (R>50 km)



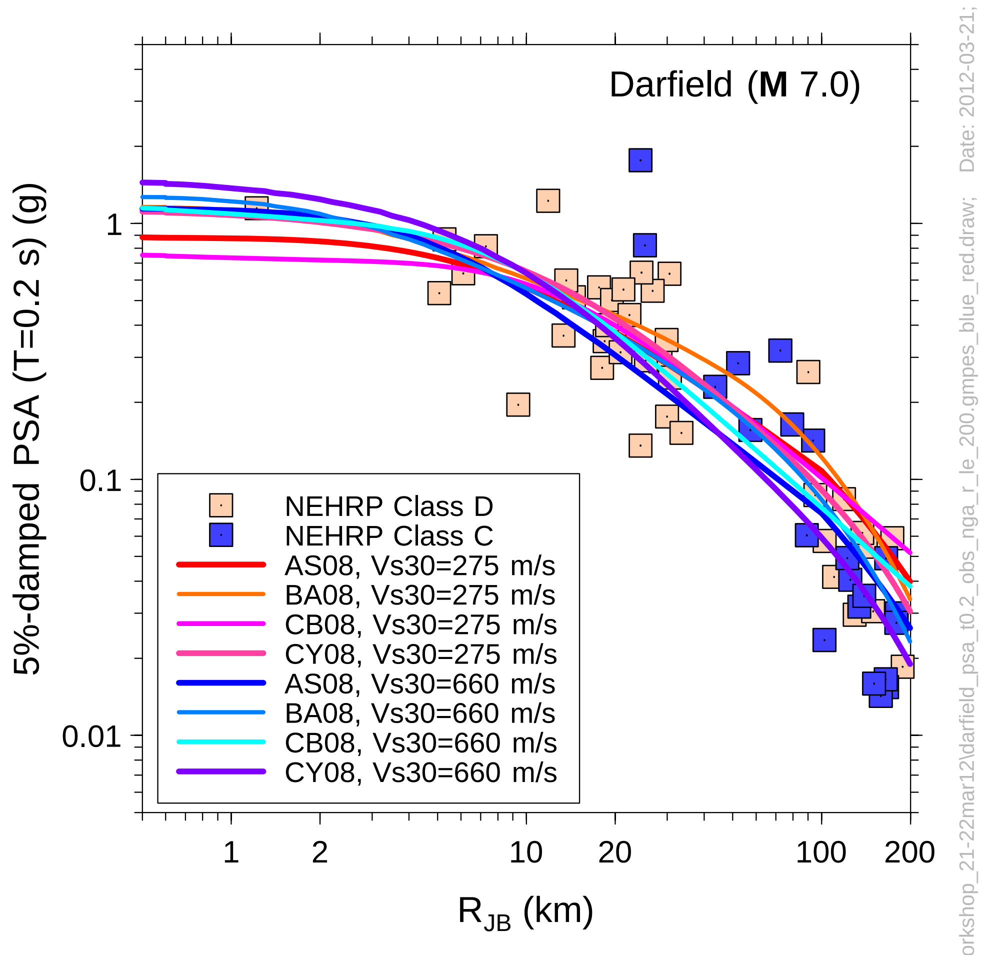
- Christchurch (**M** 6.1) class D motions now smaller than Darfield (**M** 7.0) at all distances
- Apparent site effect small or not existent



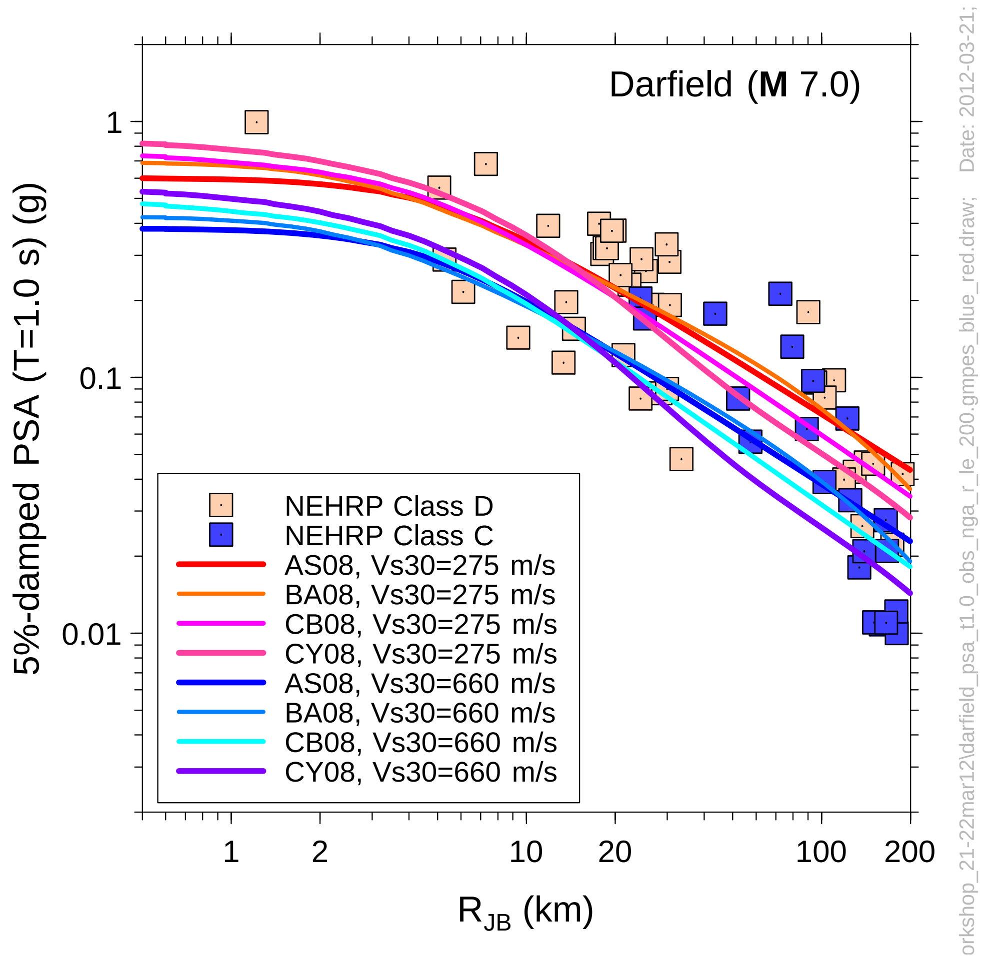
Comparison of Observed Motions and Motions from NGA-W1 GMPEs: Darfield

- Reddish GMPEs for class D
- Bluish GMPEs for class C
- Don't try to follow curves for individual GMPEs

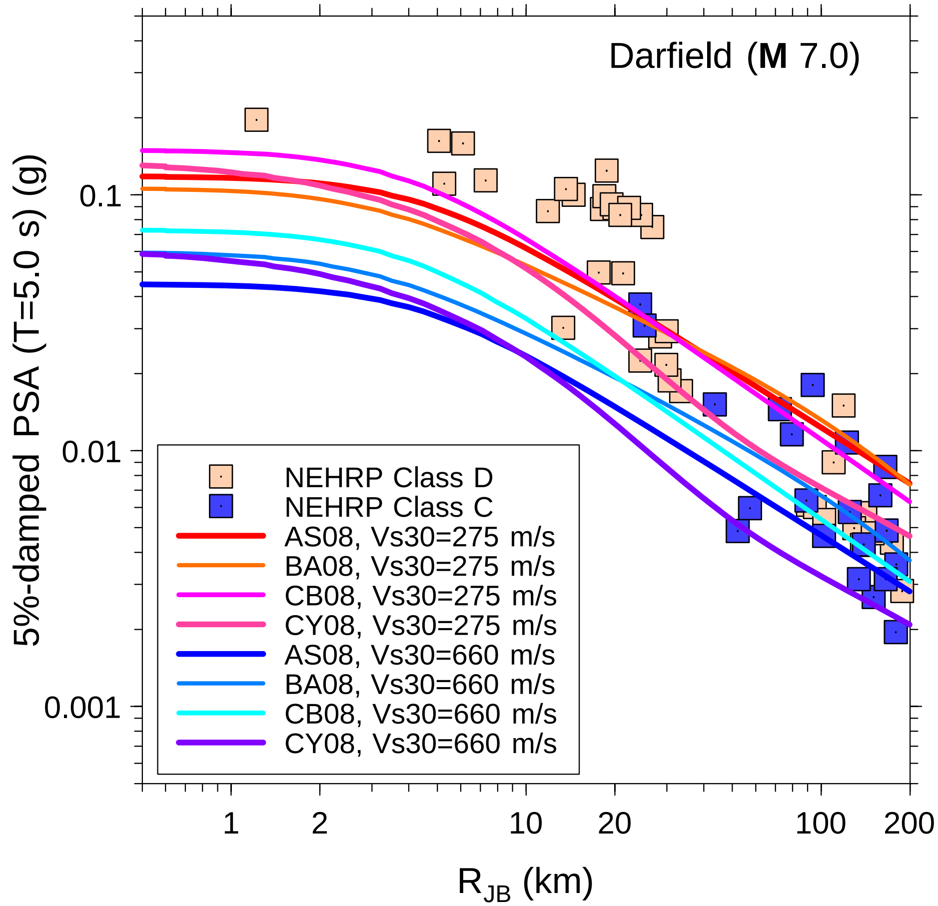
- Overall comparison good
- Apparent lack of site effect in data is consistent with GMPEs



- Note separation in observed class D values; GMPEs predictions between the two groups
- Site effect in GMPEs, but not apparent in observations (but little overlap in distance range for class C and D)



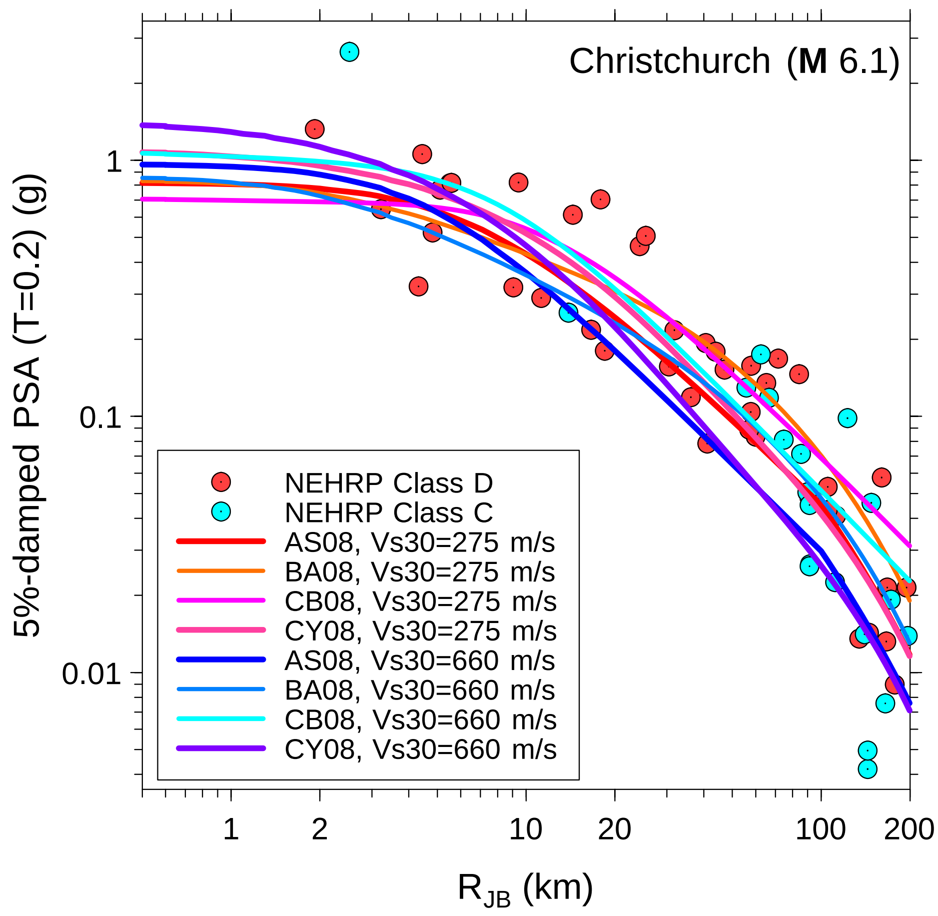
- GMPEs underpredict observations (except class C at greater distances)
- Site effect in GMPEs, but not apparent in observations (but little overlap in distance range for class C and D)



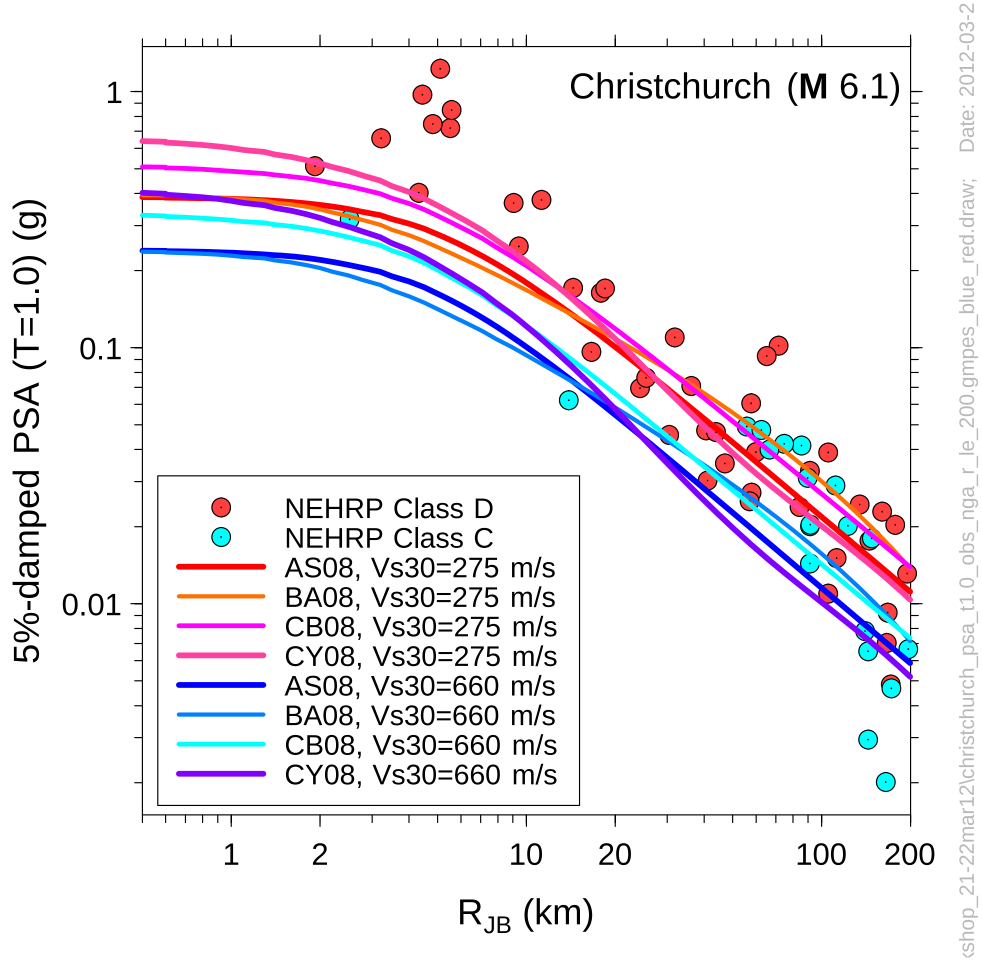
orkshop_21-22mar12\darfield_psa_t5.0_obs_nga_r_le_200.gmpes_blue_red.draw; Date: 2012-03-21;

Comparison of Observed Motions and Motions from NGA-W1 GMPEs: Christchurch

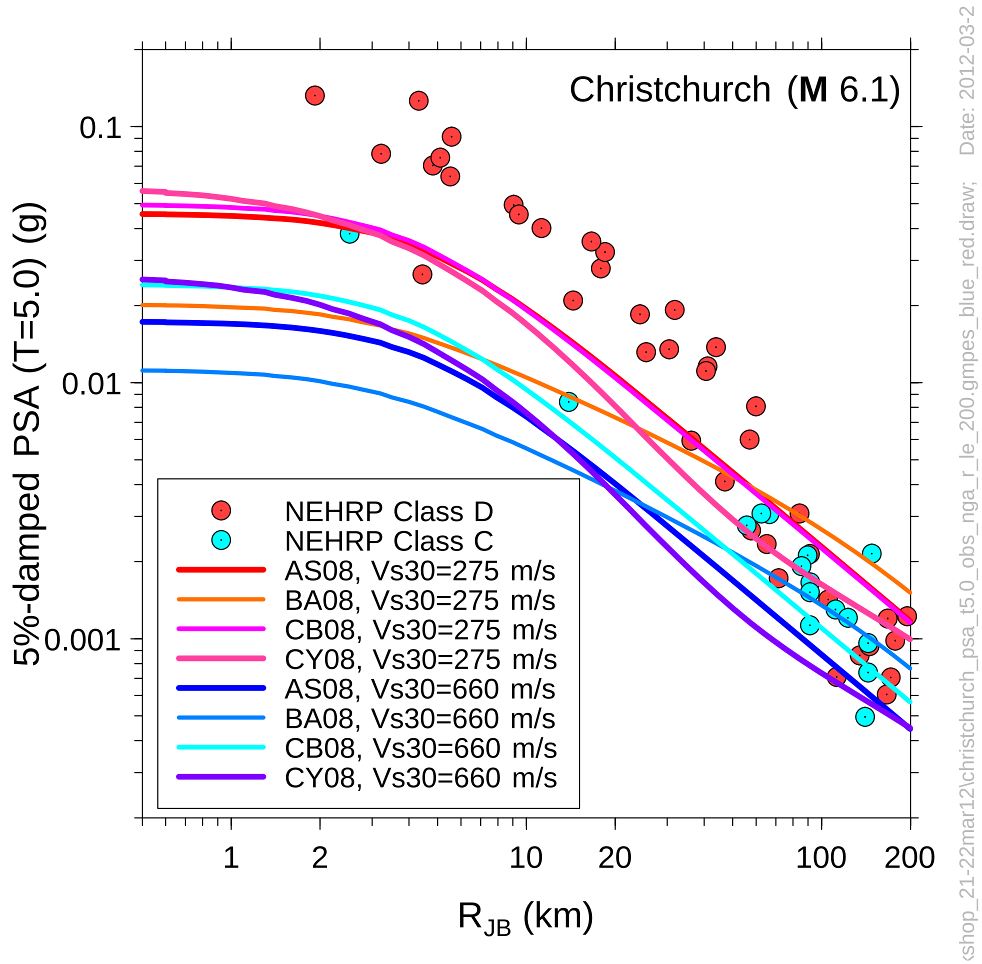
- Overall comparison good
- Apparent lack of site effect in data is consistent with GMPEs



- GMPEs tend to underpredict class D motions at close distances
- Site effect in GMPEs, but not apparent in observations (but little overlap in distance range for class C and D)

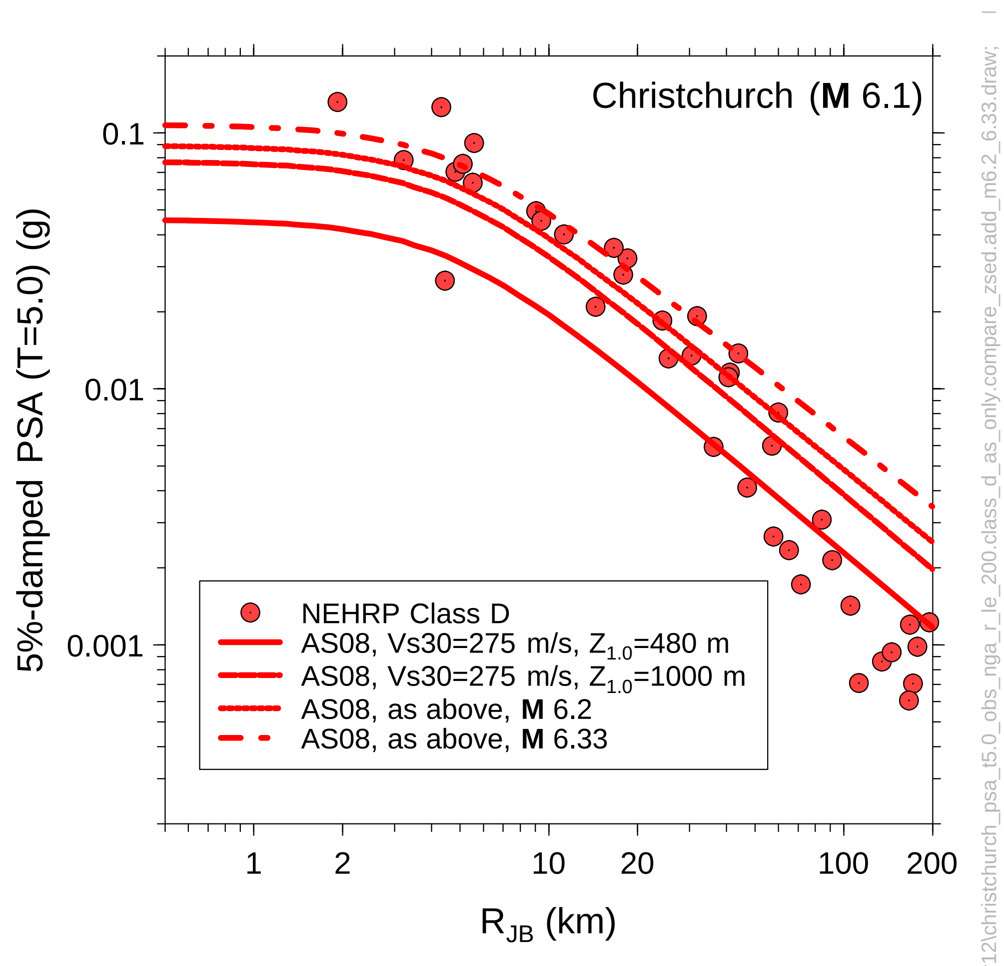


- GMPEs severely underpredict observations at shorter distances
- Agreement better for greater distances
- Site effect in GMPEs, but not apparent in observations (but little overlap in distance range for class C and D)

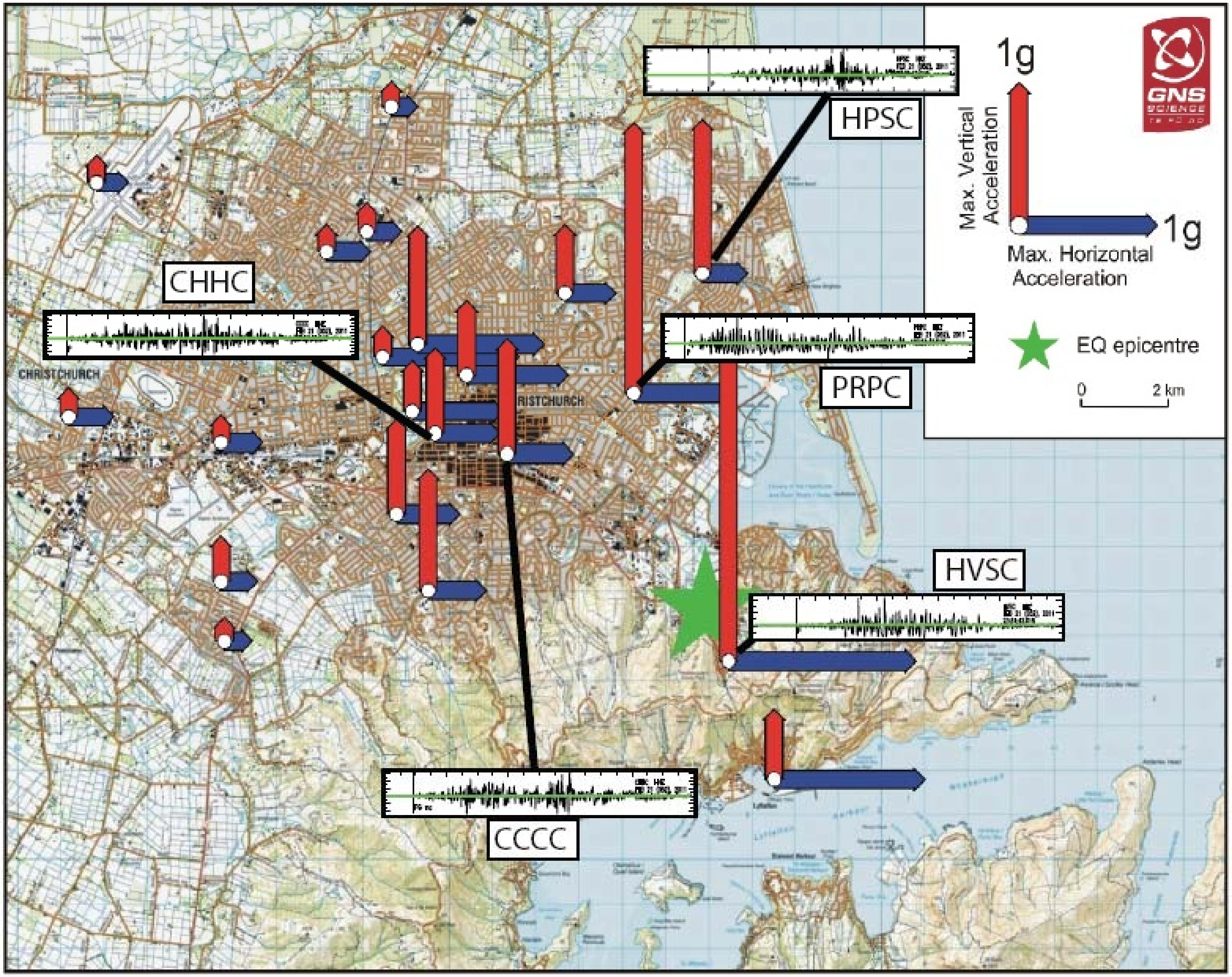


Sensitivity of Predicted T=5 s PSA to sediment depth and to magnitude

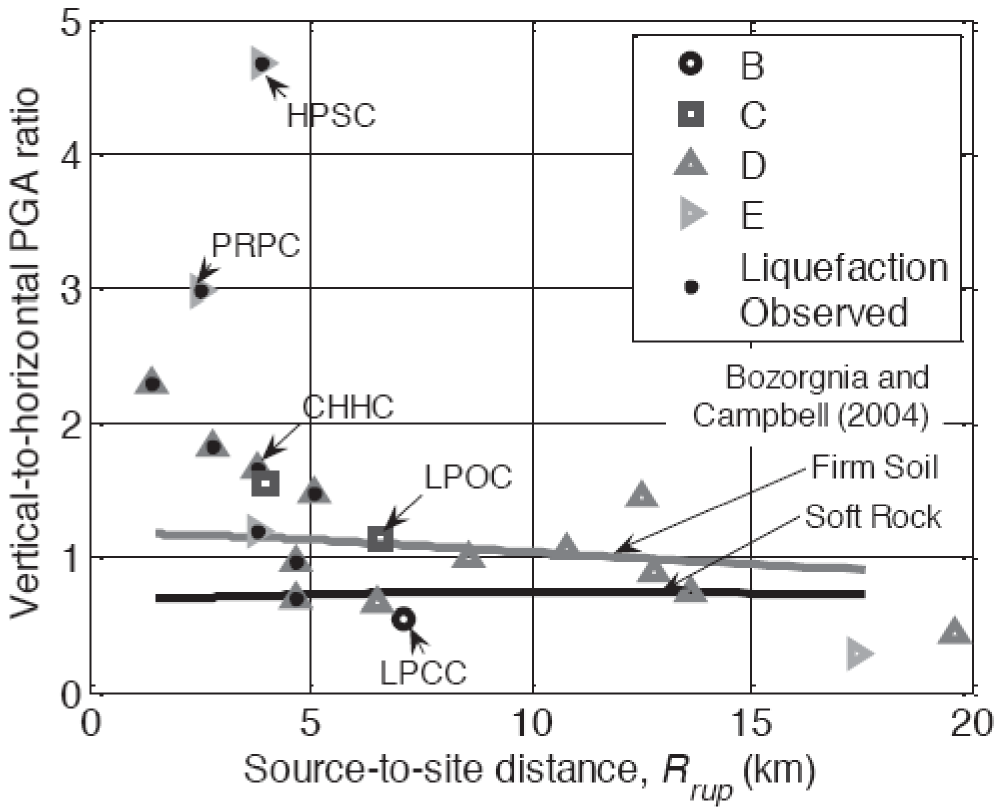
- Show AS08 and class D only
- $Z_{1.0}$=1000 m from Bradley & Cuprinovski (2011)
- **M** 6.33 from Holden (2011)
- Use of these data in NGA-W2 without $Z_{1.0}$ and larger **M** could result in biased results.
- Does $Z_{1.0}$ vary spatially, with it being smaller for stations at greater distances? If so, this would help explain the discrepancy at greater distance. This could also be due to a difference in geometrical spreading due to lateral changes in crustal structure.



Vertical Motion



(Fry et al., 2011)

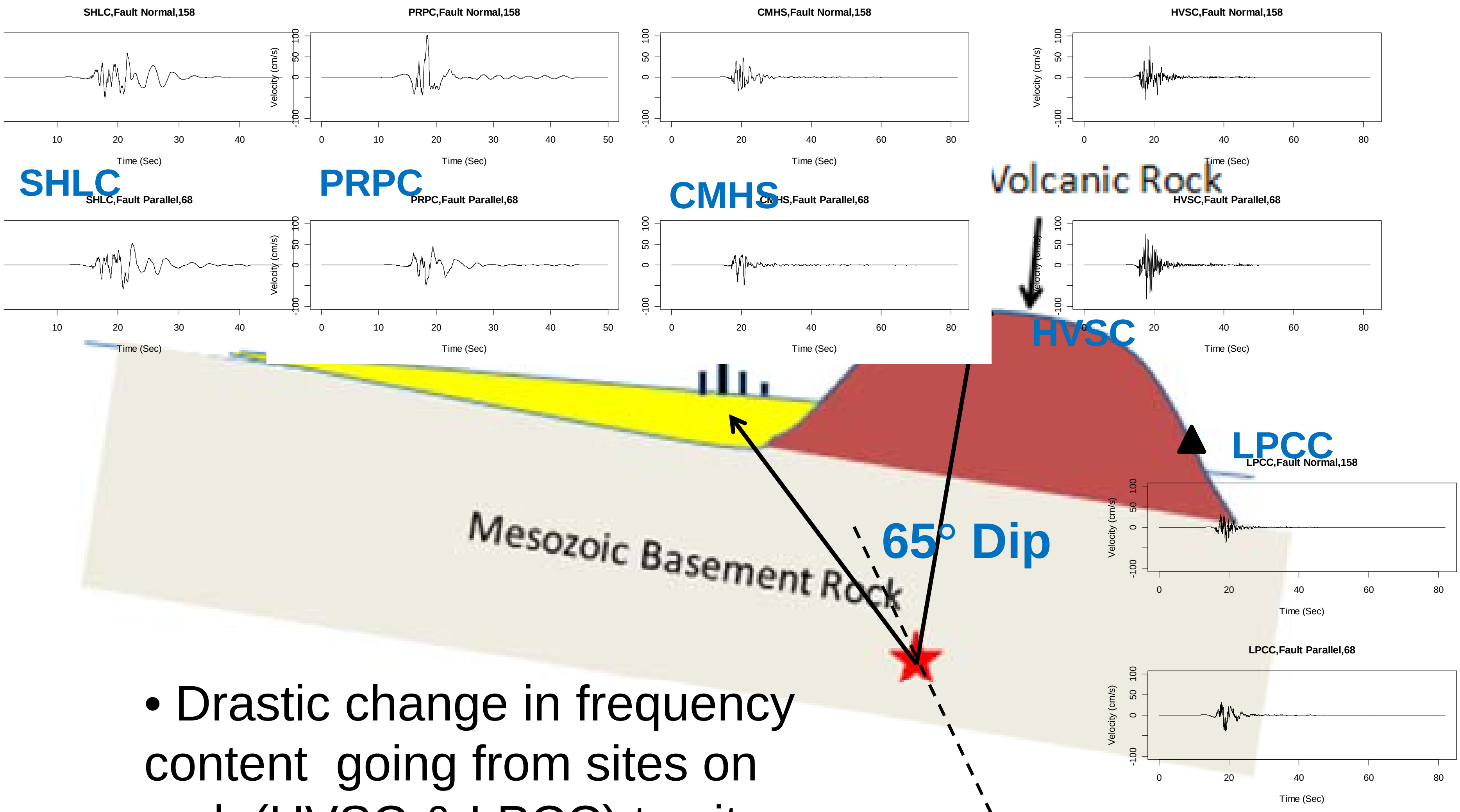


(Bradley & Cuprinovski, 2011)

Effects Producing Spatial Variability in Ground Motions

- Source: Radiation Pattern & Directivity
- Path: volcanic vs sediments
- Basin Waves
- Sediment Depth
- Shallow Site Response
  - Linear
  - Nonlinear

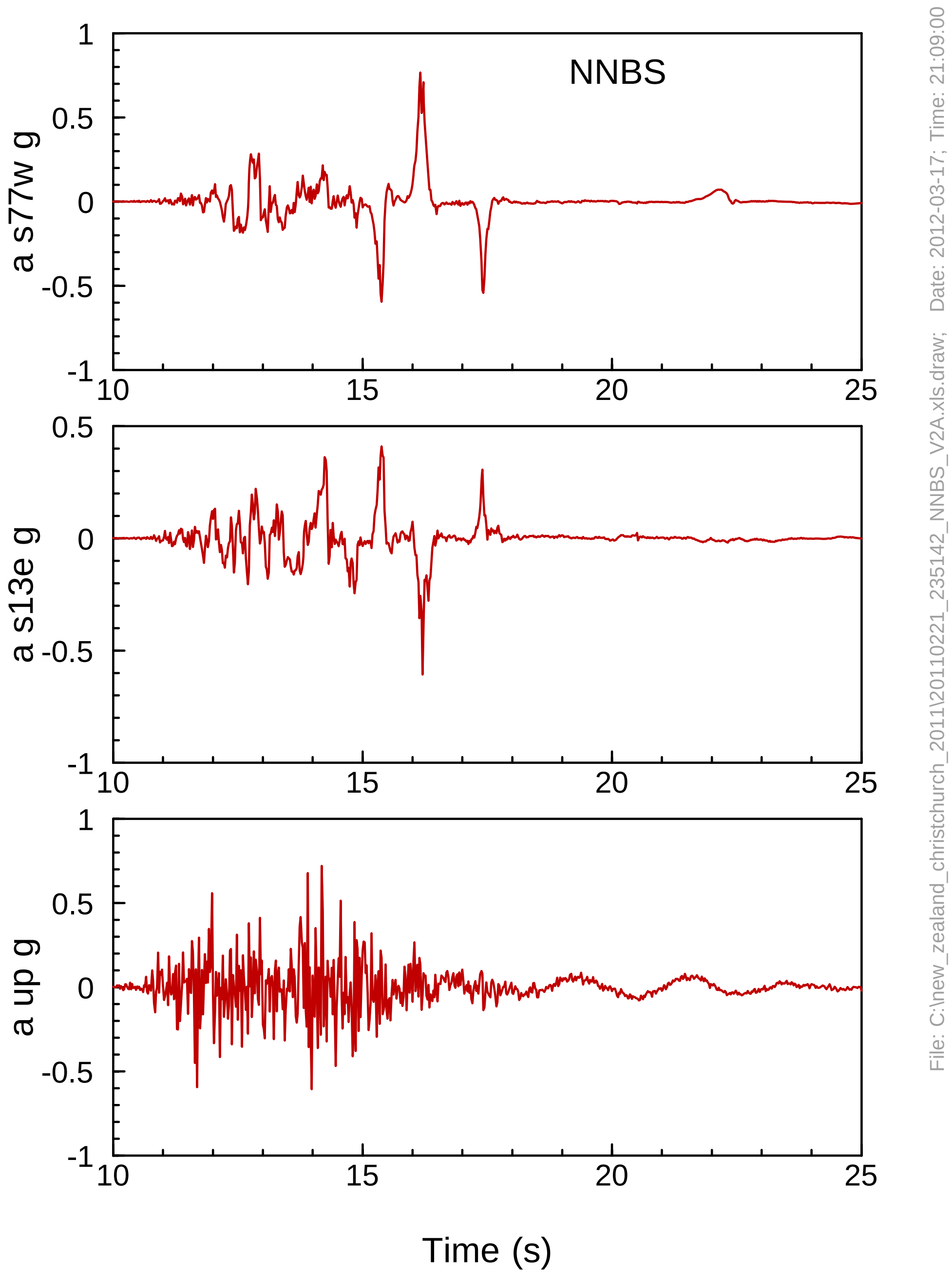
Fault Normal and Fault Parallel Velocity Time Seri



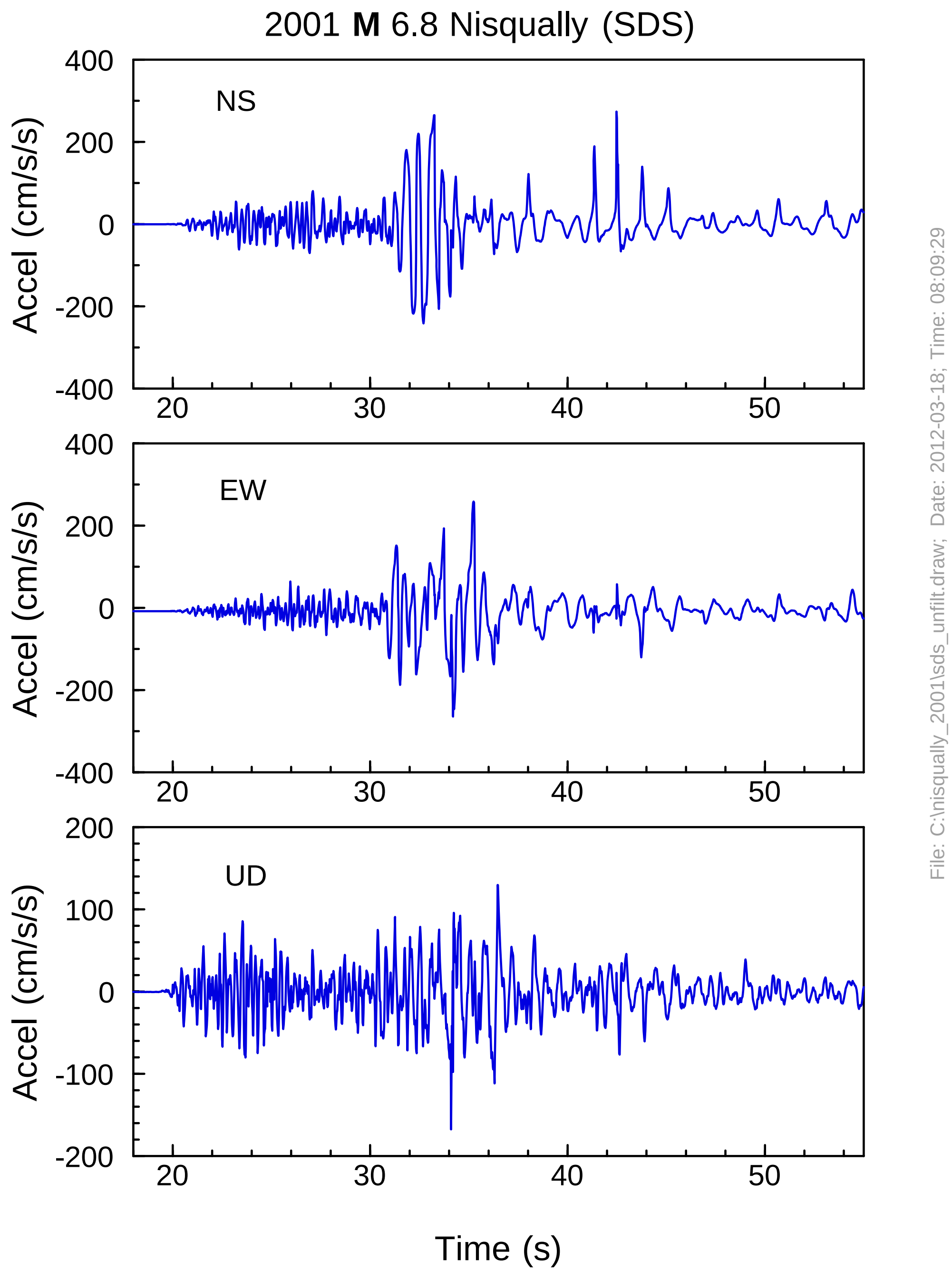
- Drastic change in frequency content going from sites on rock (HVSC & LPCC) to sites on Quaternary sediments.

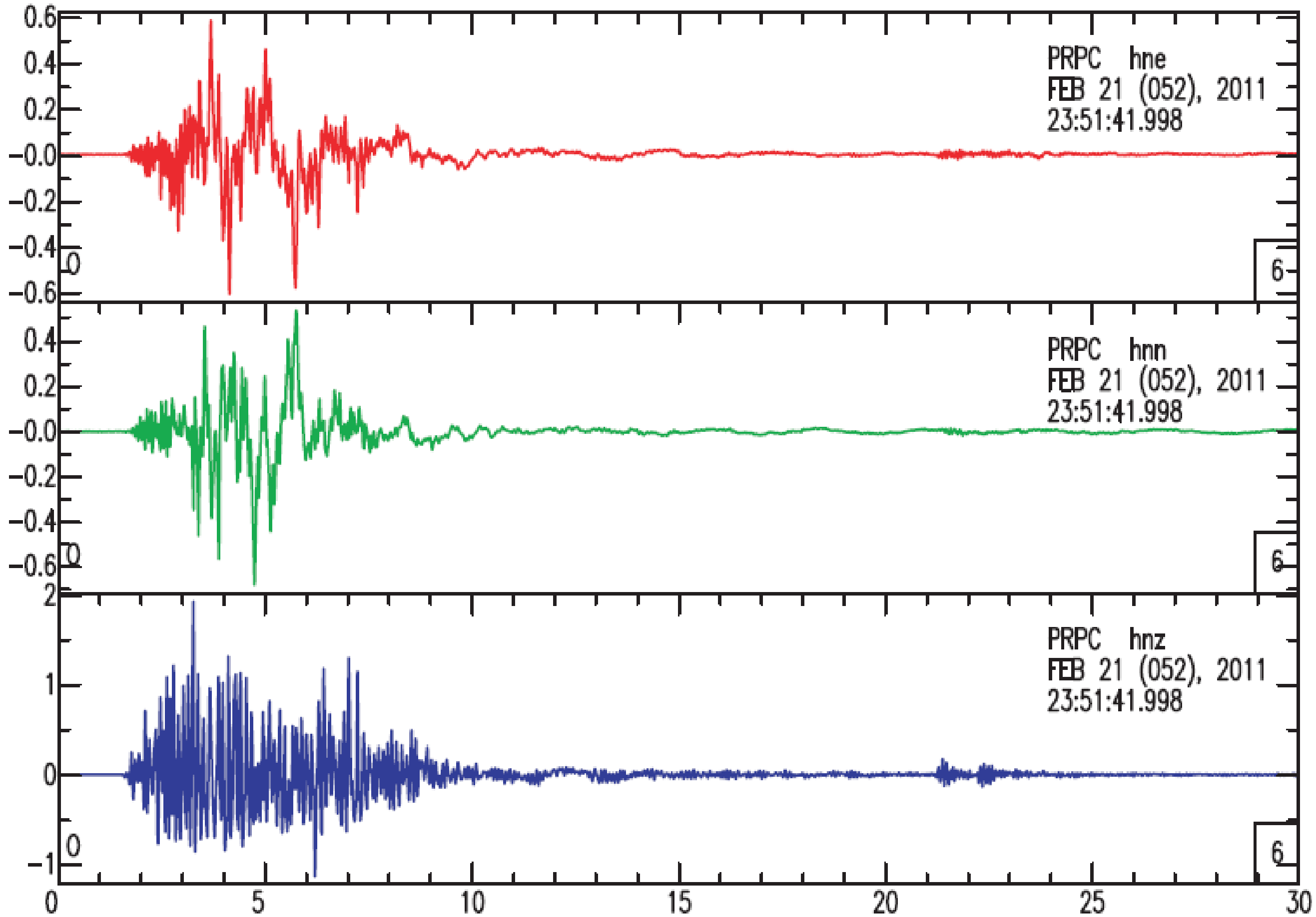
(from B. Chiou)

Evidence for Nonlinear Soil Response


NNBS
a s77w g
a s13e g
a up g
1
0.5
0
-0.5
-1
10
15
20
25
Time (s)
File: C:\new_zealand_christchurch_2011\20110221_235142_NNBS_V2A.xls.draw;   Date: 2012-03-17; Time: 21:09:00

(see Frankel et al., 2002, for details)





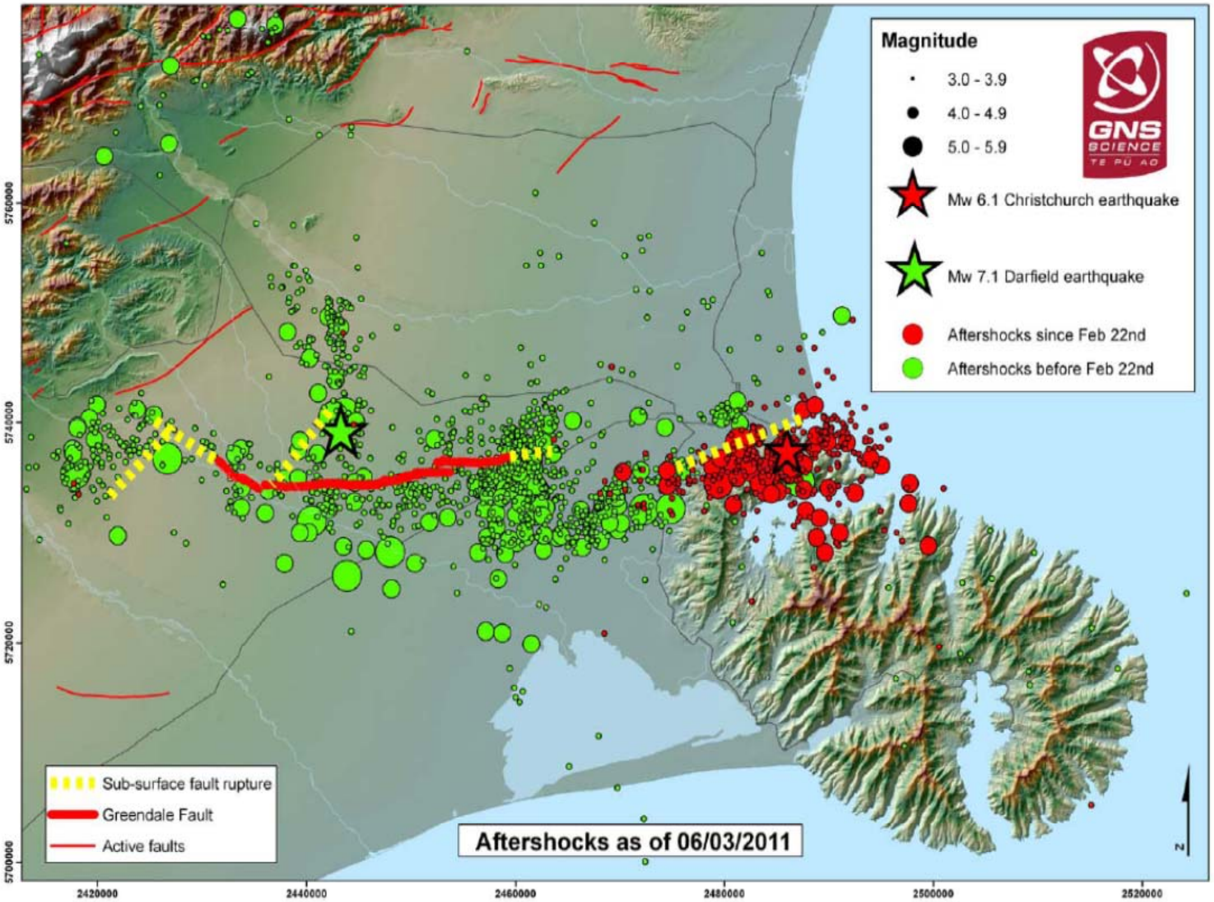
Negative vertical accelerations are “clipped”. This may be due to a different nonlinear process than that producing the cusps shown in the previous figures.

(Fry et al., 2011)

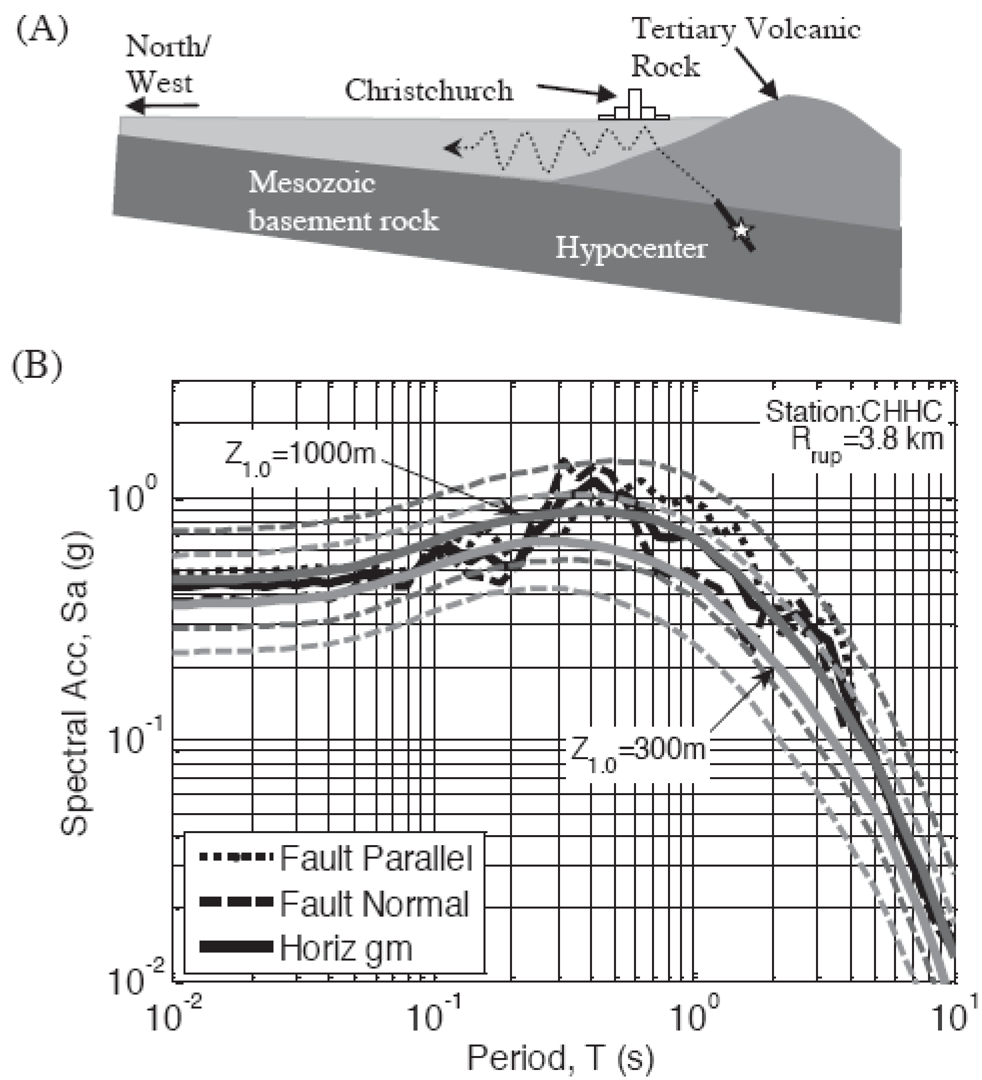
Conclusions

- **M** 7.0 Darfield and **M** 6.1 Christchurch motions similar for close distances, short periods
- **M** 7.0 Darfield motions higher than **M** 6.1 Christchurch motions for longer periods (as expected from the difference in magnitudes)
- Site response not too obvious, but this may be because of the different spatial distributions of the site classes (most close sites are class D)
- Observed motions influenced by many effects, including
  - Lateral changes in geology
  - Local linear and nonlinear site response
  - Basin waves (?)
- GMPEs are in reasonable agreement with observations for close distances, short periods
- GMPEs underpredict longer period motions, using metadata in current NGA-W2 flatfile

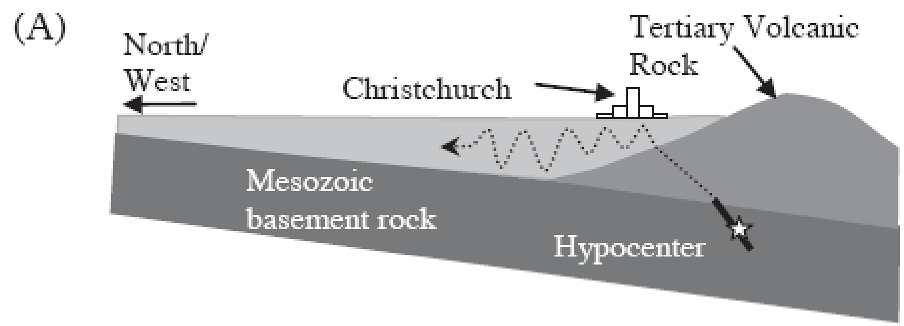
END



From B. Chiou, Source: GNS Science

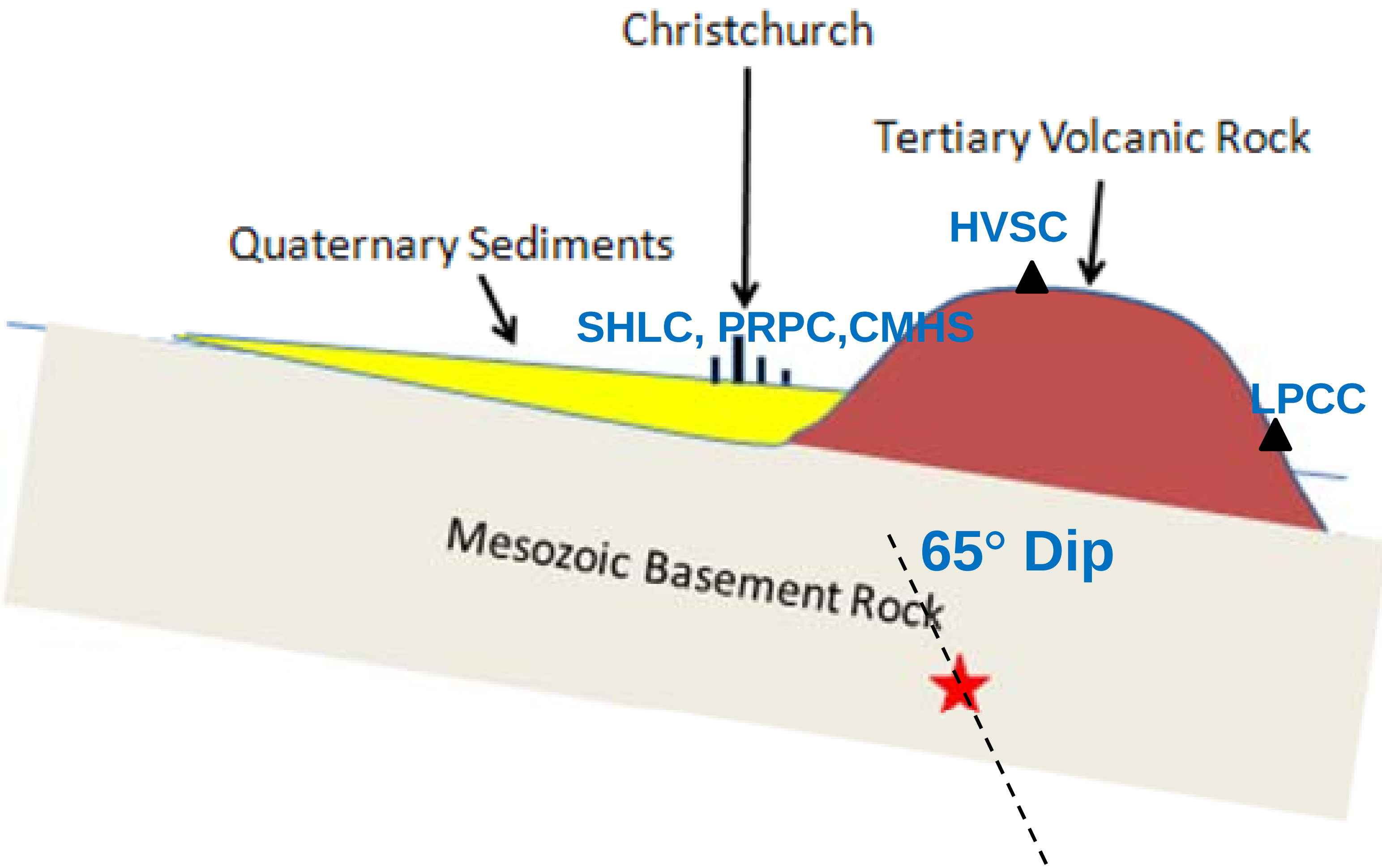


(Bradley & Cuprinovski, 2011)



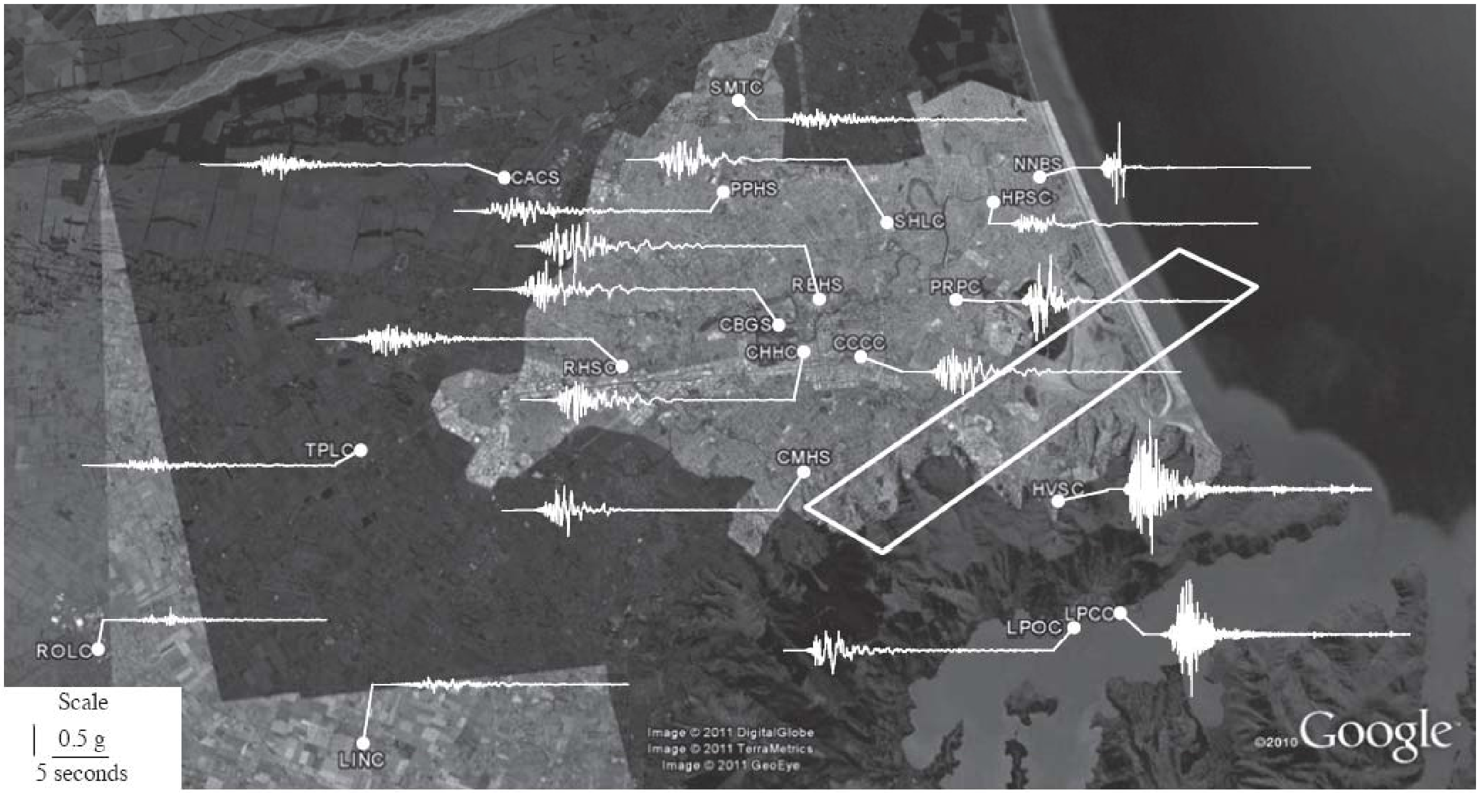
(Bradley & Cuprinovski, 2011)

Directivity Effect and Velocity Pulse

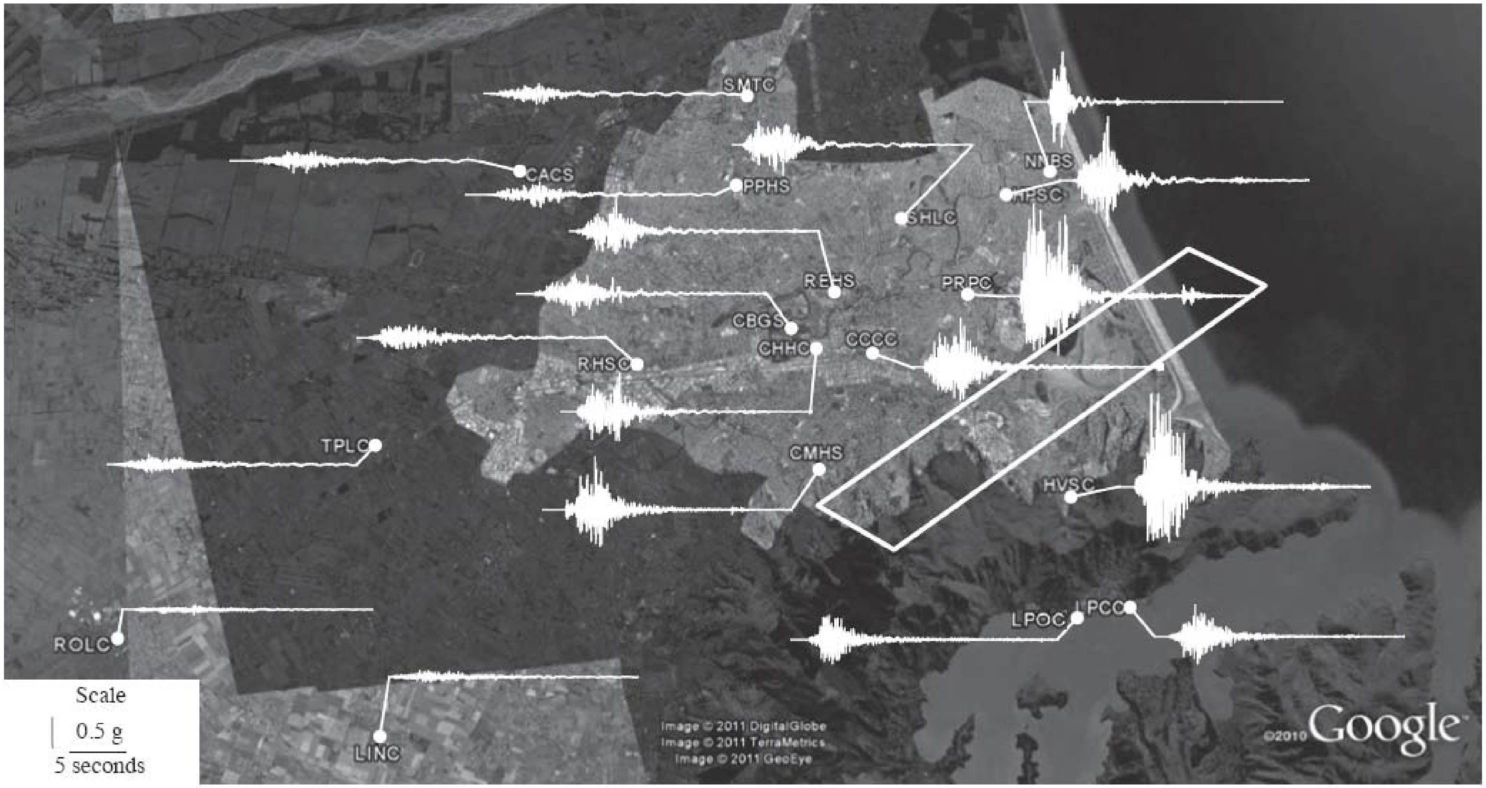


Source: George Walker

(from B. Chiou)

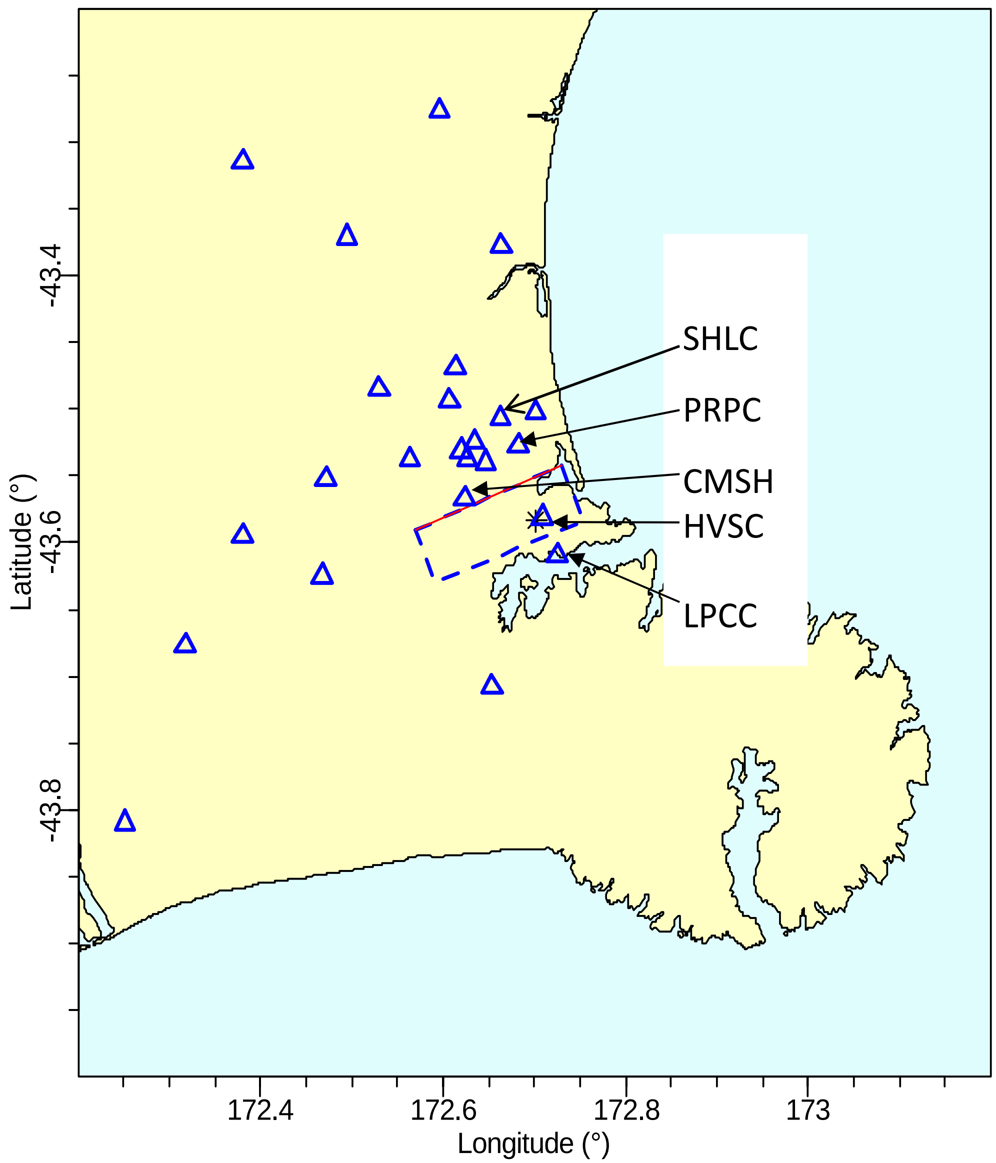


(Bradley & Cuprinovski, 2011)



(Bradley & Cuprinovski, 2011)

0282 Christchurch, New Zealand



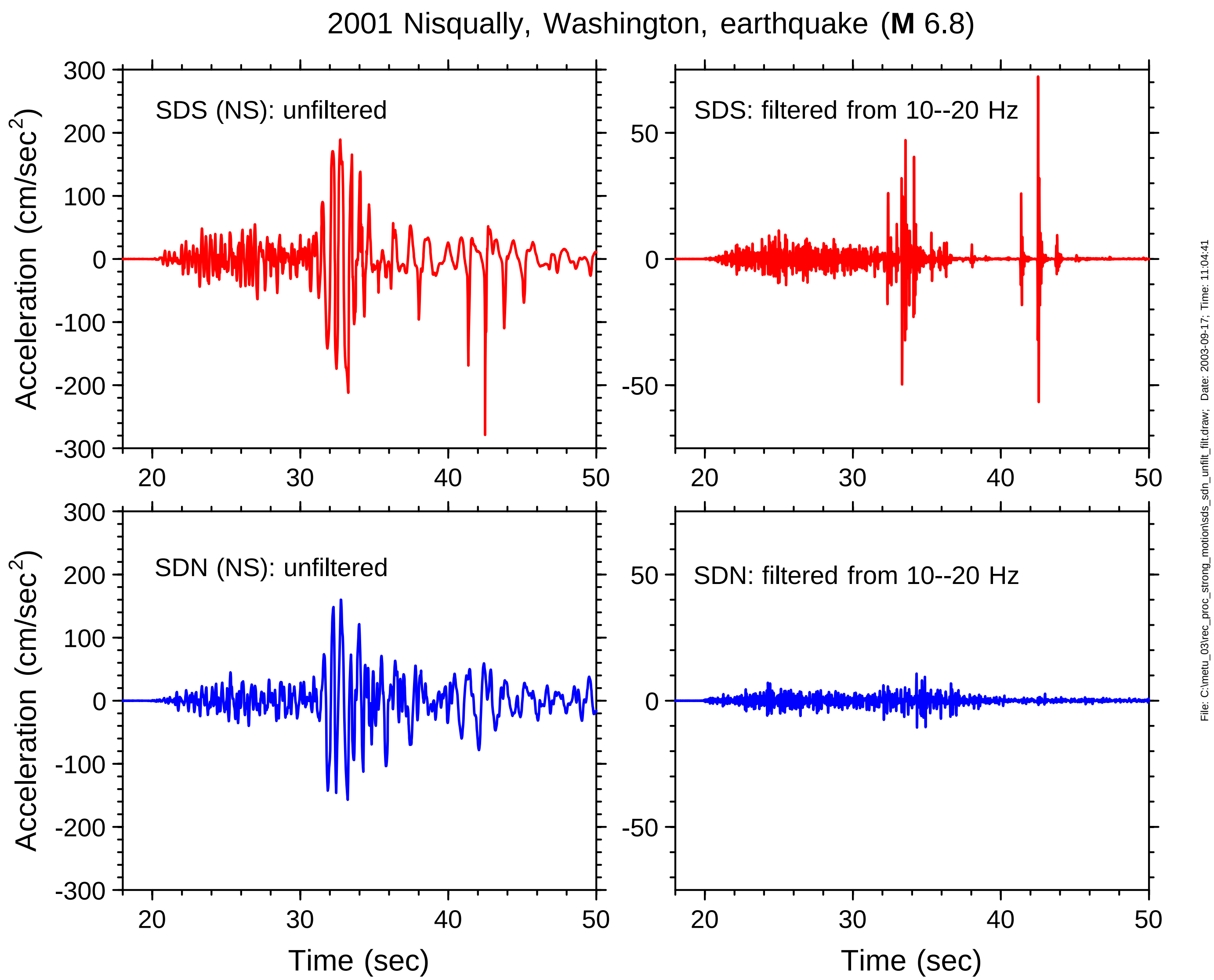
(from B. Chiou)

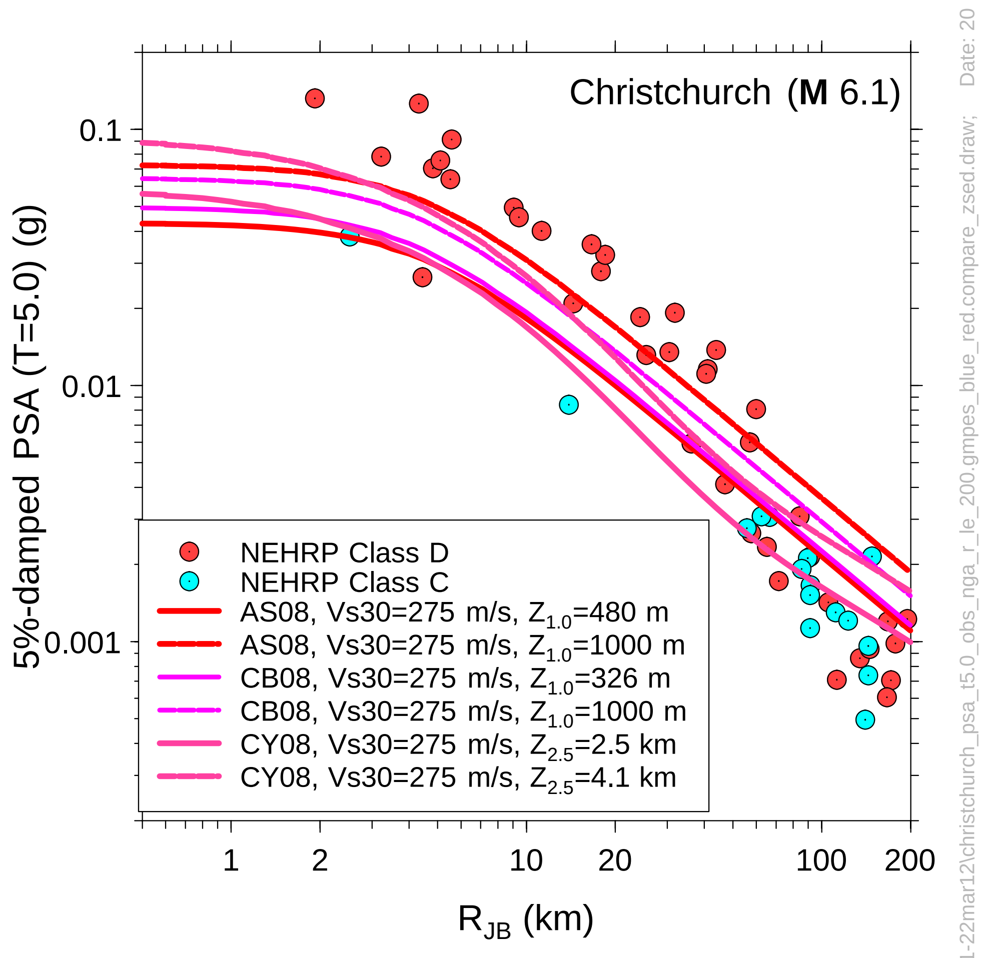
Fault Rupture

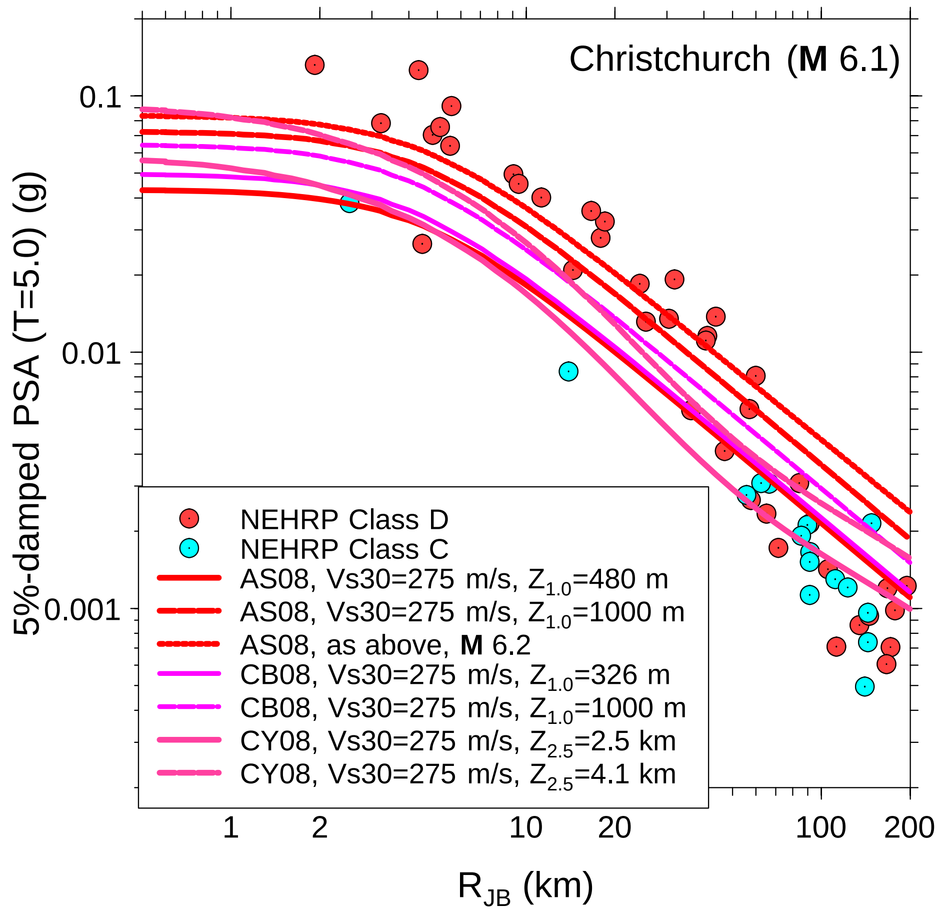
- Reverse faulting on a buried fault
- Assumed fault plane
  - Strike = 68° (from USGS CMT)
  - 65 ° dip, to the south
  - Top of rupture is at 2 km depth (assumed)
  - Bottom of rupture is at 12 km (assumed)
  - Rupture length ~ 15 km (length of the aftershock zone).

(from B. Chiou)

- SDS within 200 m of SDN
- liquefaction at SDS, not at SDN
- Note cusps at SDS and increased amplitude at high frequencies




Christchurch (**M** 6.1)
5%-damped PSA (T=5.0) (g)
0.1
0.01
0.001
1
2
10
20
100
200
R_{JB} (km)
NEHRP Class D
NEHRP Class C
AS08, Vs30=275 m/s, $Z_{1.0}$=480 m
AS08, Vs30=275 m/s, $Z_{1.0}$=1000 m
CB08, Vs30=275 m/s, $Z_{1.0}$=326 m
CB08, Vs30=275 m/s, $Z_{1.0}$=1000 m
CY08, Vs30=275 m/s, $Z_{2.5}$=2.5 km
CY08, Vs30=275 m/s, $Z_{2.5}$=4.1 km
1-22mar12\christchurch_psa_t5.0_obs_nga_r_le_200.gmpes_blue_red.compare_zsed.draw; Date: 20



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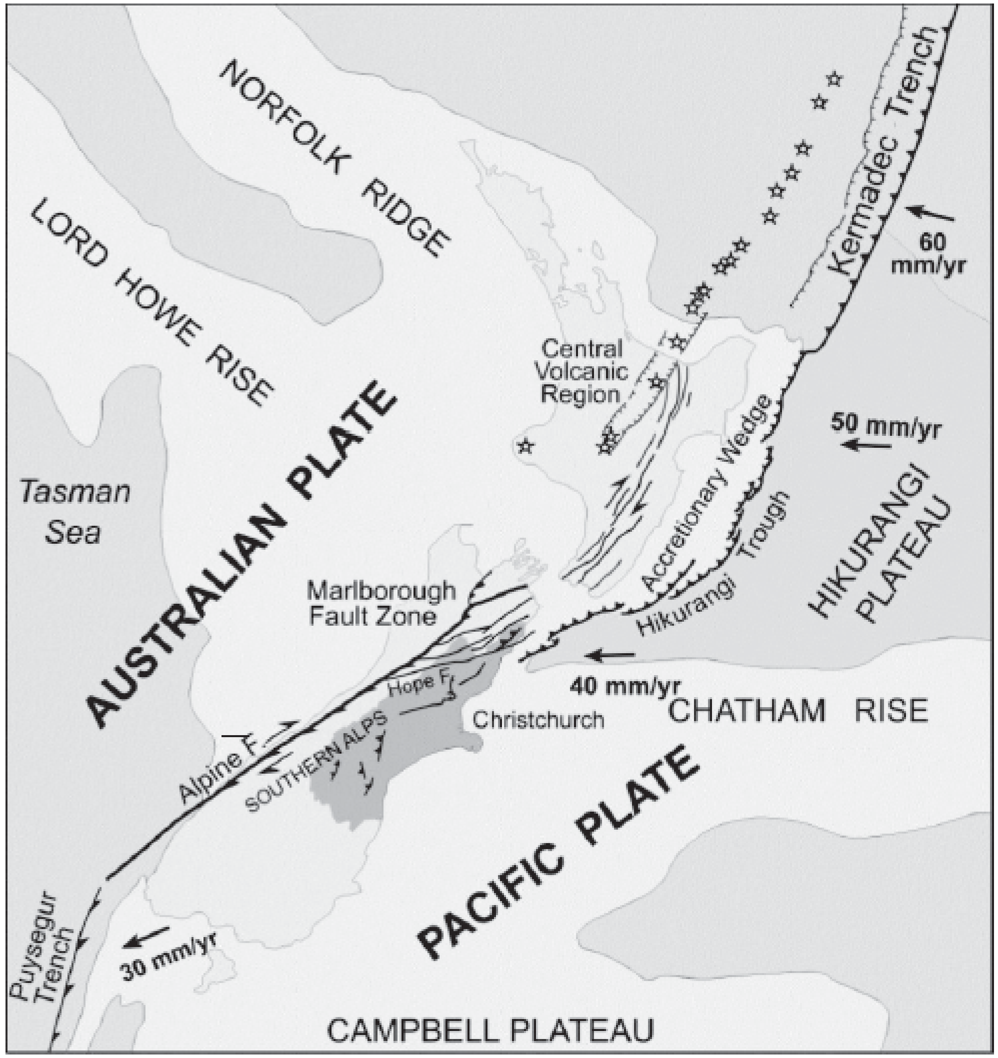
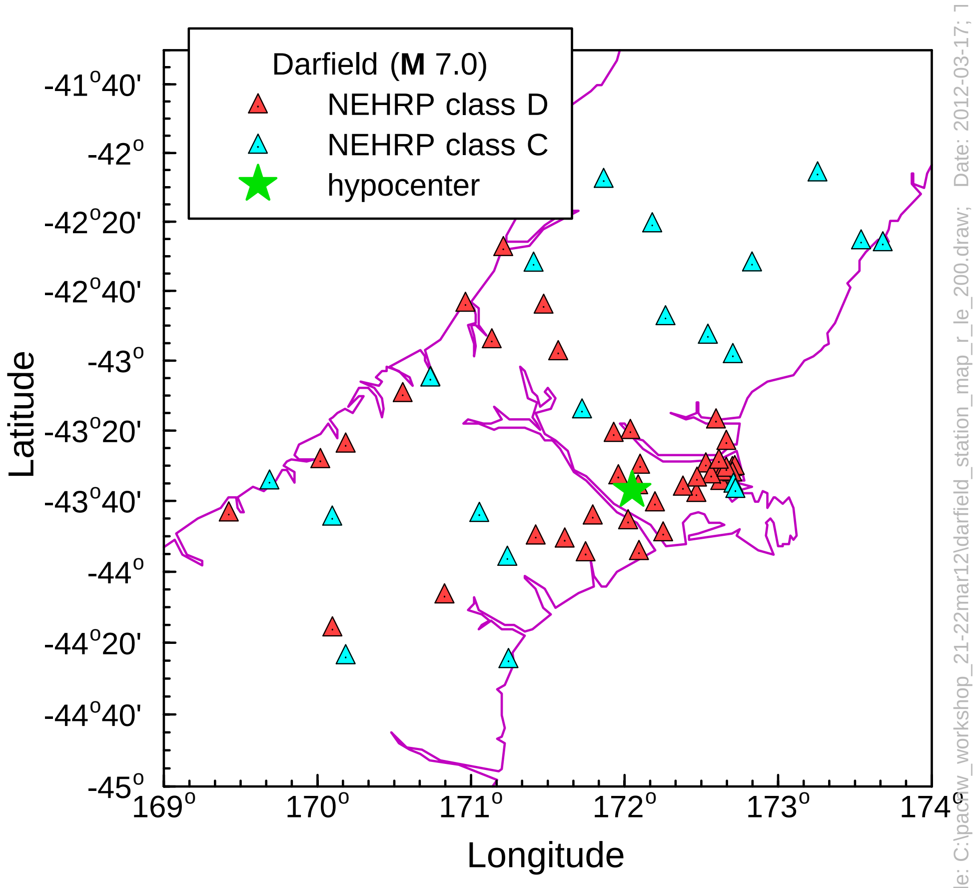
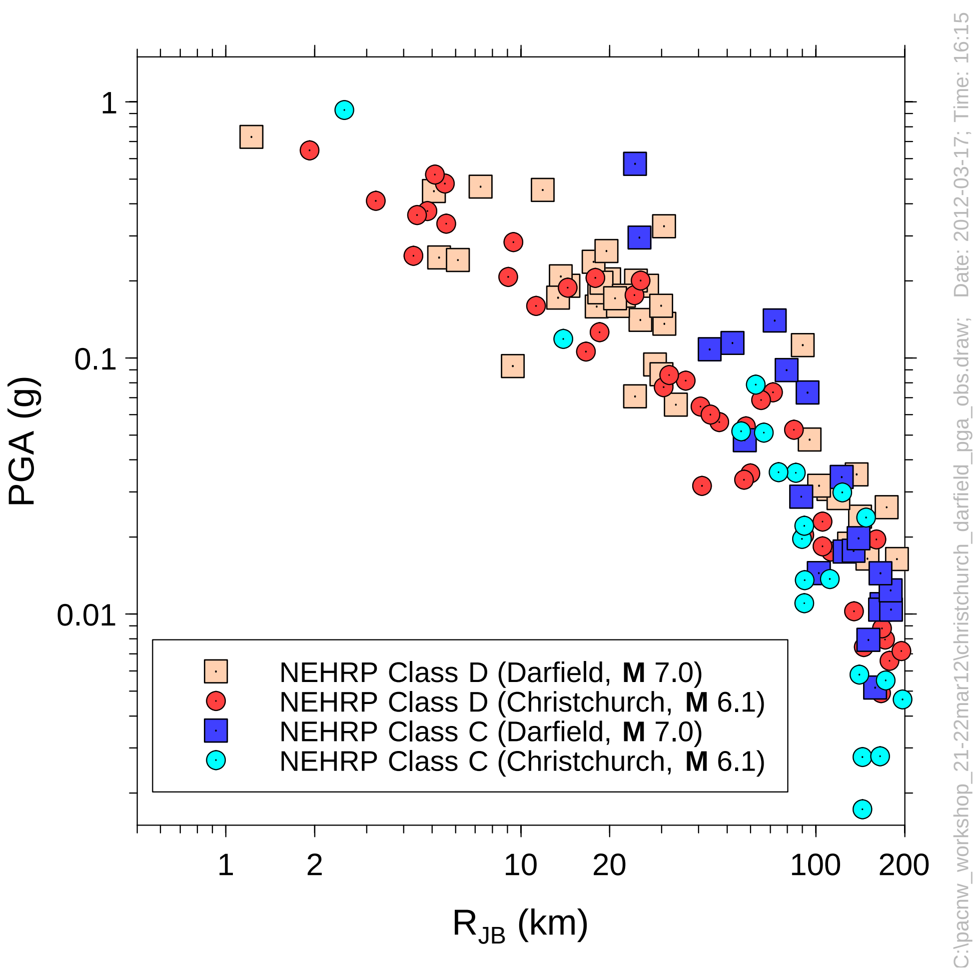


(Bradley & Cuprinovski, 2011)

Stations for which Rjb<= 200 km





PGA (g)
1
0.1
0.01
1
2
10
20
100
200
R_{JB} (km)
NEHRP Class D (Darfield, **M** 7.0)
NEHRP Class D (Christchurch, **M** 6.1)
NEHRP Class C (Darfield, **M** 7.0)
NEHRP Class C (Christchurch, **M** 6.1)
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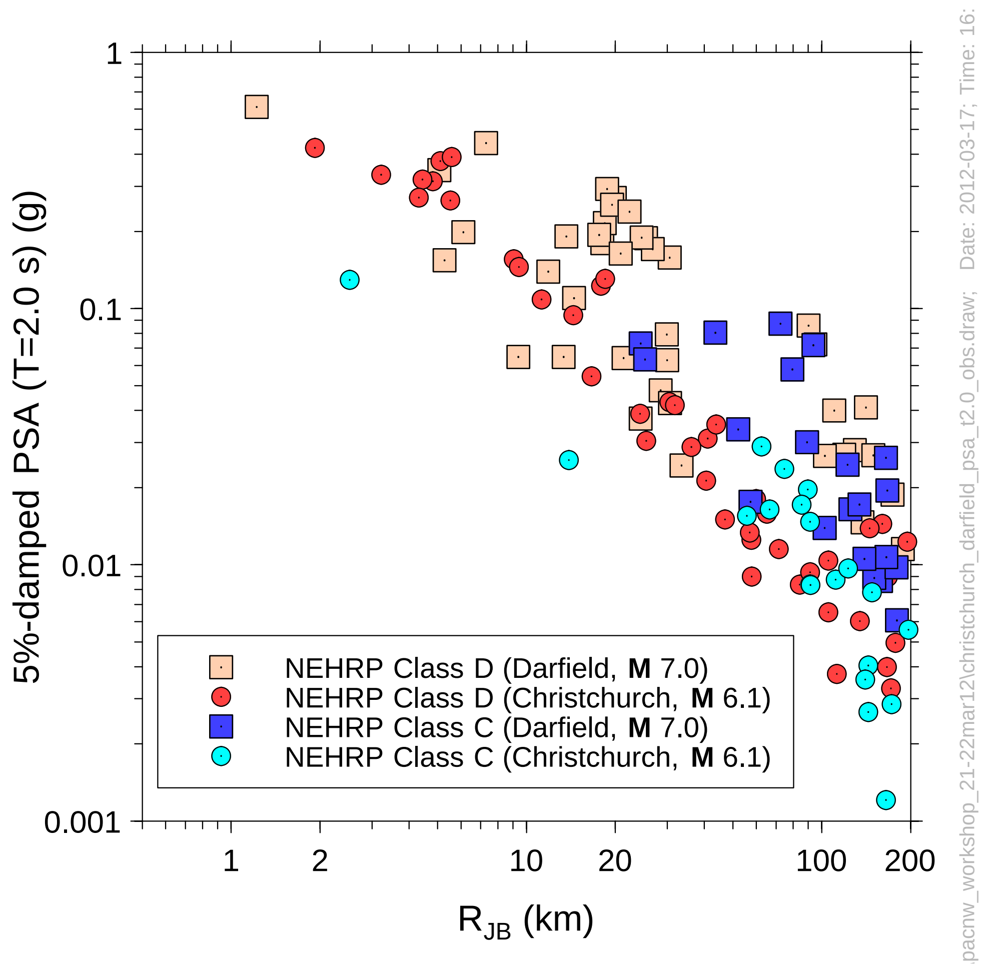
5%-damped PSA (T=2.0 s) (g)
1
0.1
0.01
0.001
1
2
10
20
100
200
RJB (km)
NEHRP Class D (Darfield, M 7.0)
NEHRP Class D (Christchurch, M 6.1)
NEHRP Class C (Darfield, M 7.0)
NEHRP Class C (Christchurch, M 6.1)
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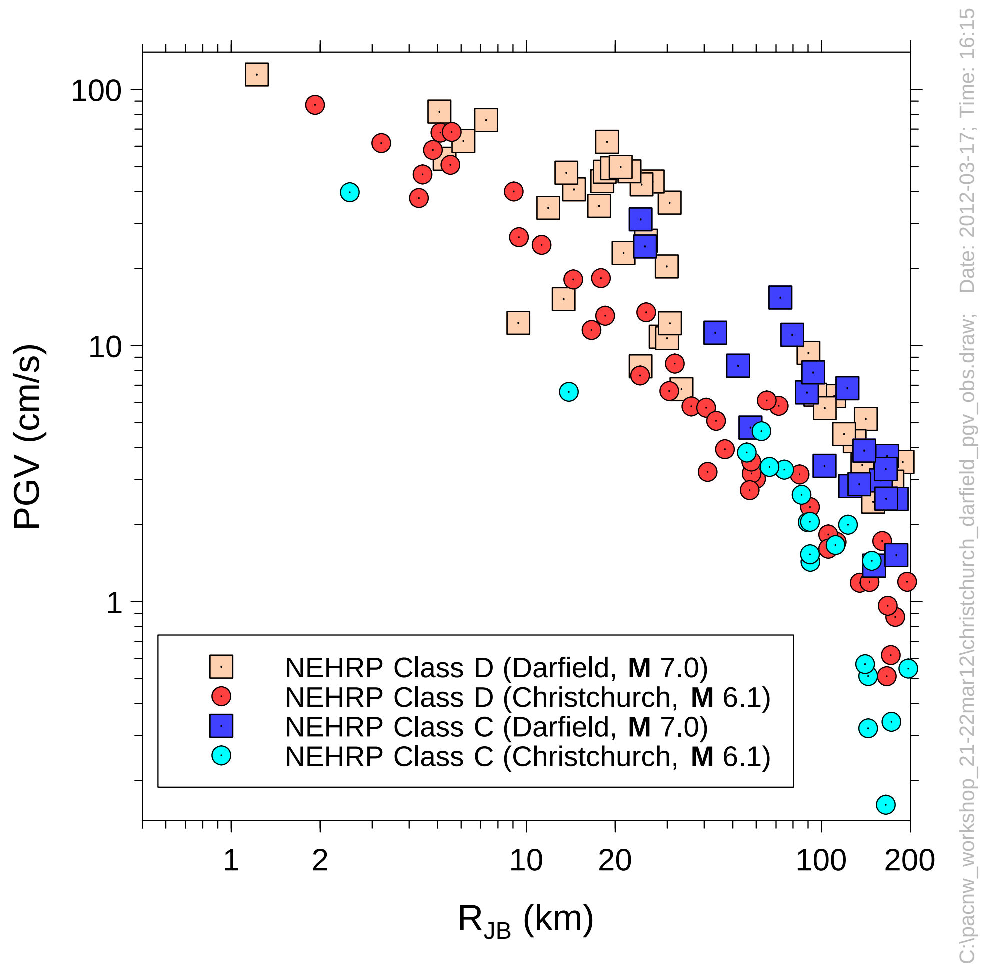

PGV (cm/s)
100
10
1
1
2
10
20
100
200
R_JB (km)
NEHRP Class D (Darfield, M 7.0)
NEHRP Class D (Christchurch, M 6.1)
NEHRP Class C (Darfield, M 7.0)
NEHRP Class C (Christchurch, M 6.1)
C:\pacnw_workshop_21-22mar12\christchurch_darfield_pgv_obs.draw; Date: 2012-03-17; Time: 16:15

Observed RotD50 reduced to GMRotI50 using factors from Boore (2010); maximum effect is 4% at T=5 s.

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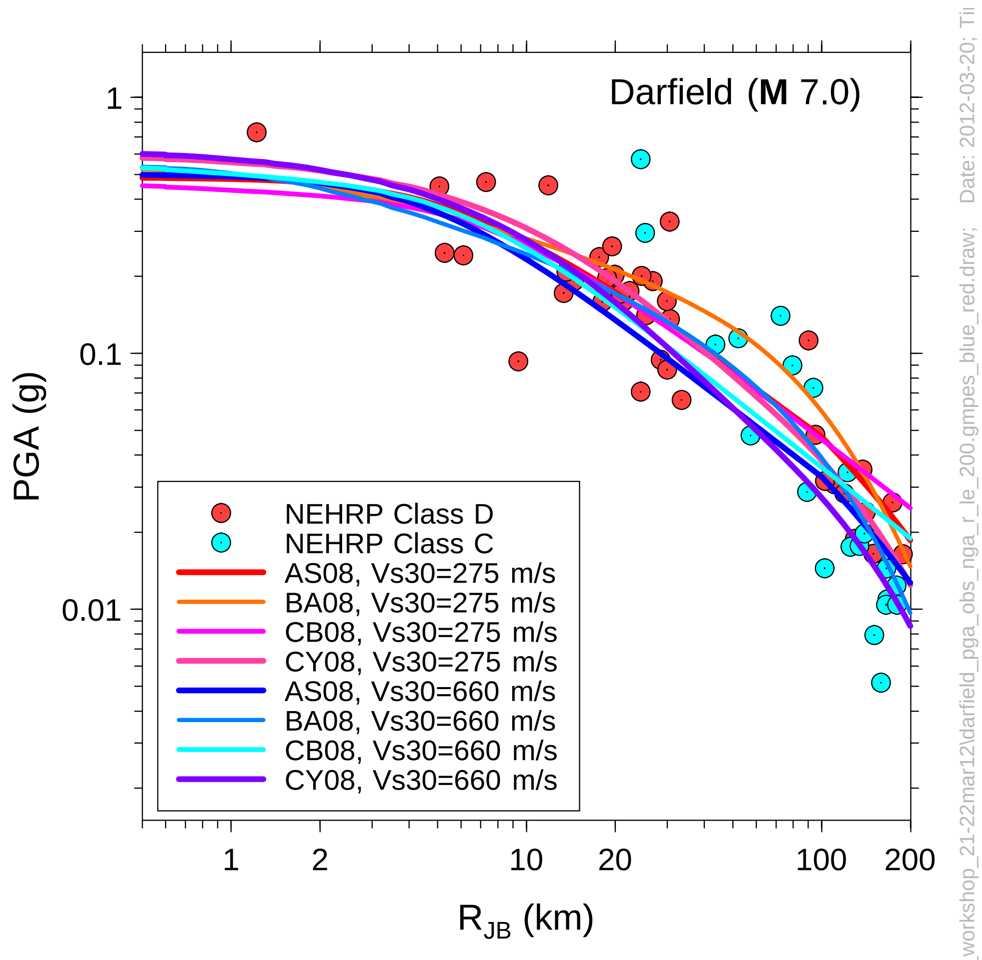
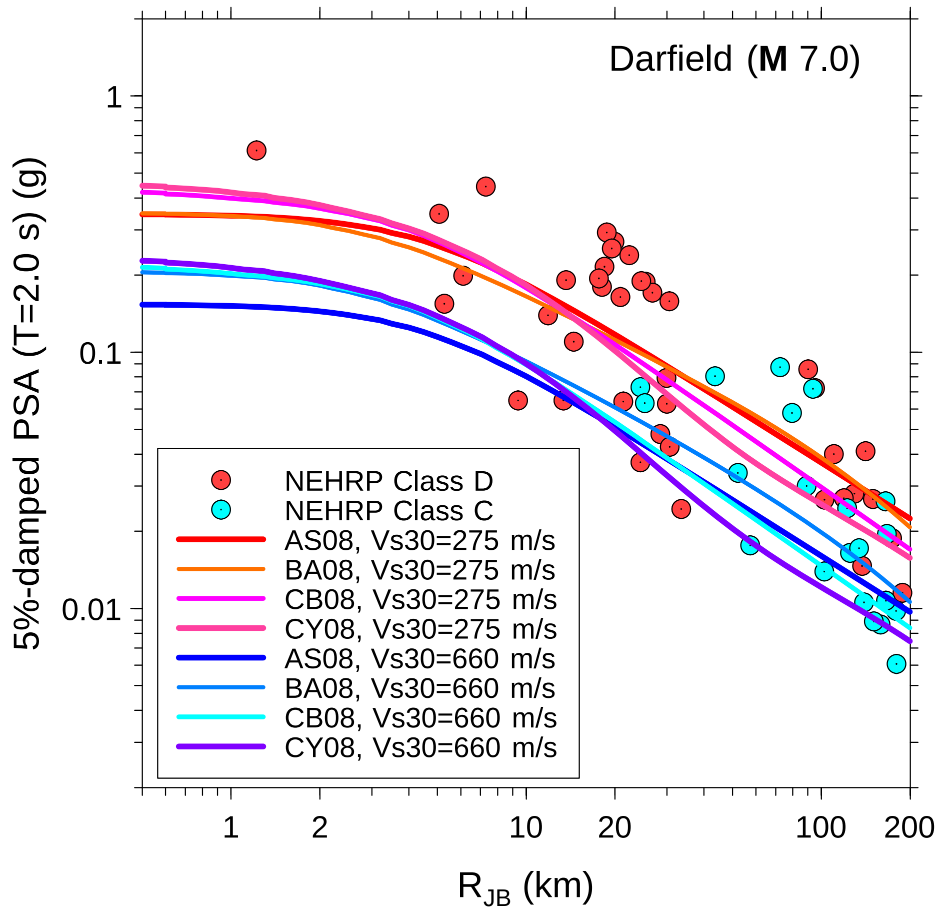
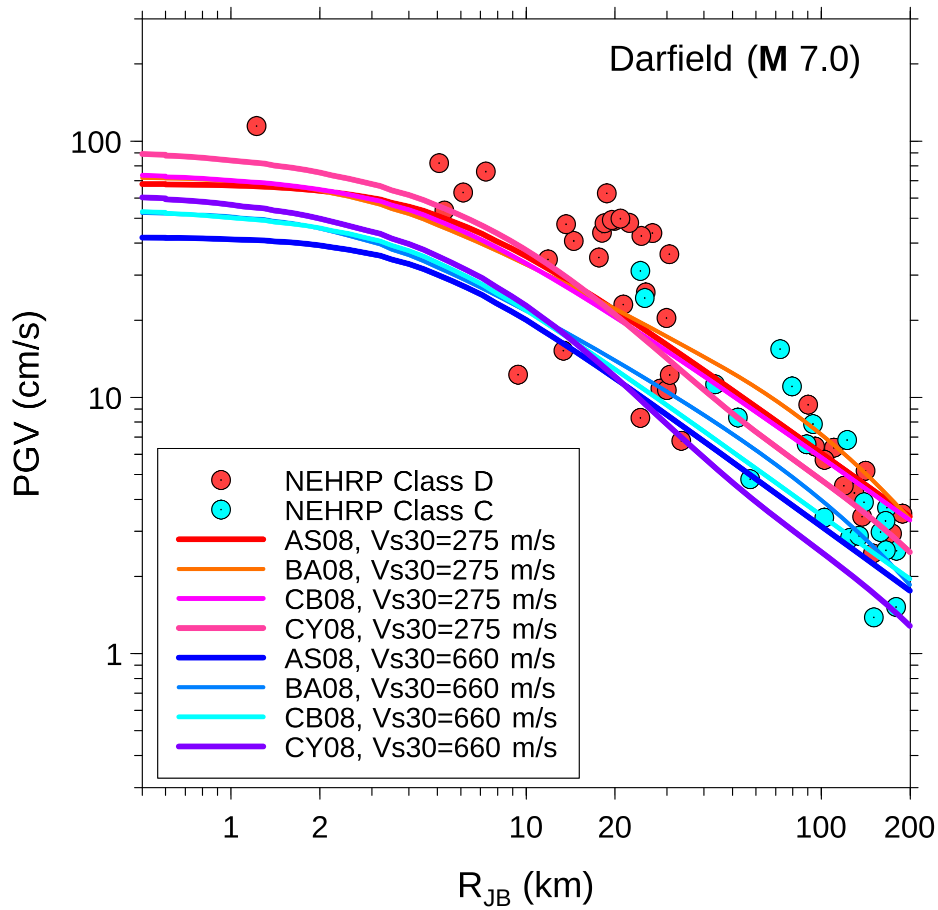




Darfield (**M** 7.0)
5%-damped PSA (T=2.0 s) (g)
1
0.1
0.01
1
2
10
20
100
200
R_{JB} (km)
NEHRP Class D
NEHRP Class C
AS08, Vs30=275 m/s
BA08, Vs30=275 m/s
CB08, Vs30=275 m/s
CY08, Vs30=275 m/s
AS08, Vs30=660 m/s
BA08, Vs30=660 m/s
CB08, Vs30=660 m/s
CY08, Vs30=660 m/s


Darfield (**M** 7.0)
PGV (cm/s)
100
10
1
R_{JB} (km)
1
2
10
20
100
200
NEHRP Class D
NEHRP Class C
AS08, Vs30=275 m/s
BA08, Vs30=275 m/s
CB08, Vs30=275 m/s
CY08, Vs30=275 m/s
AS08, Vs30=660 m/s
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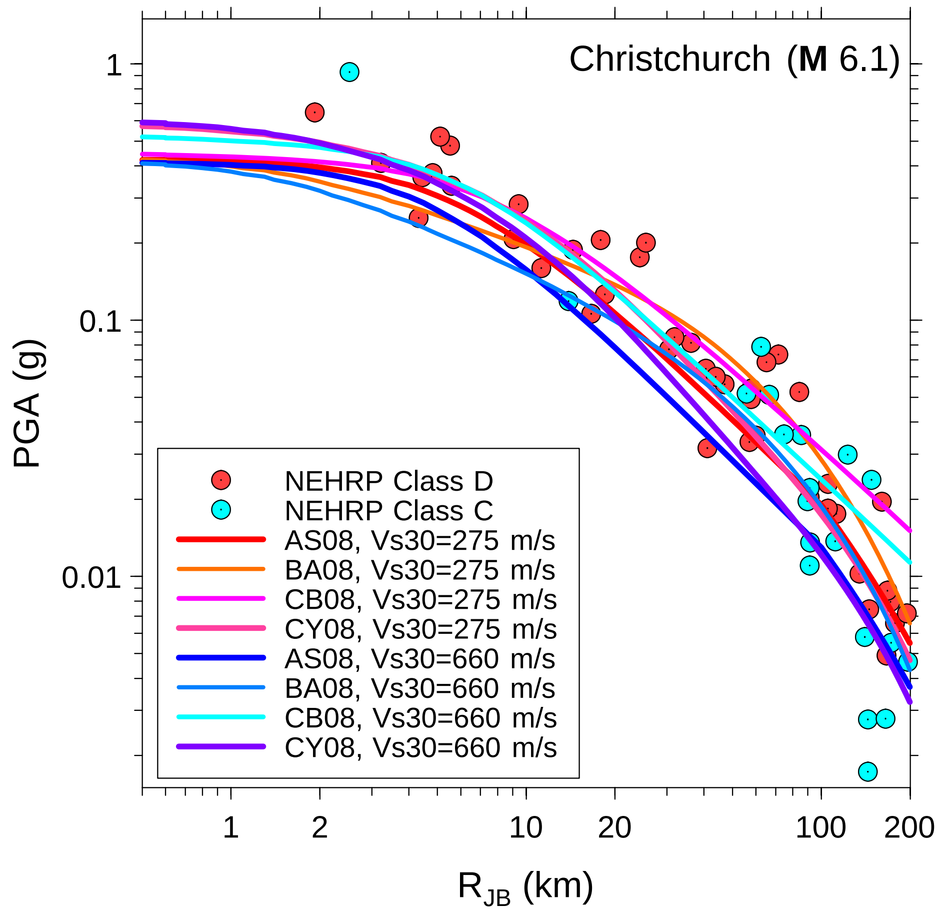
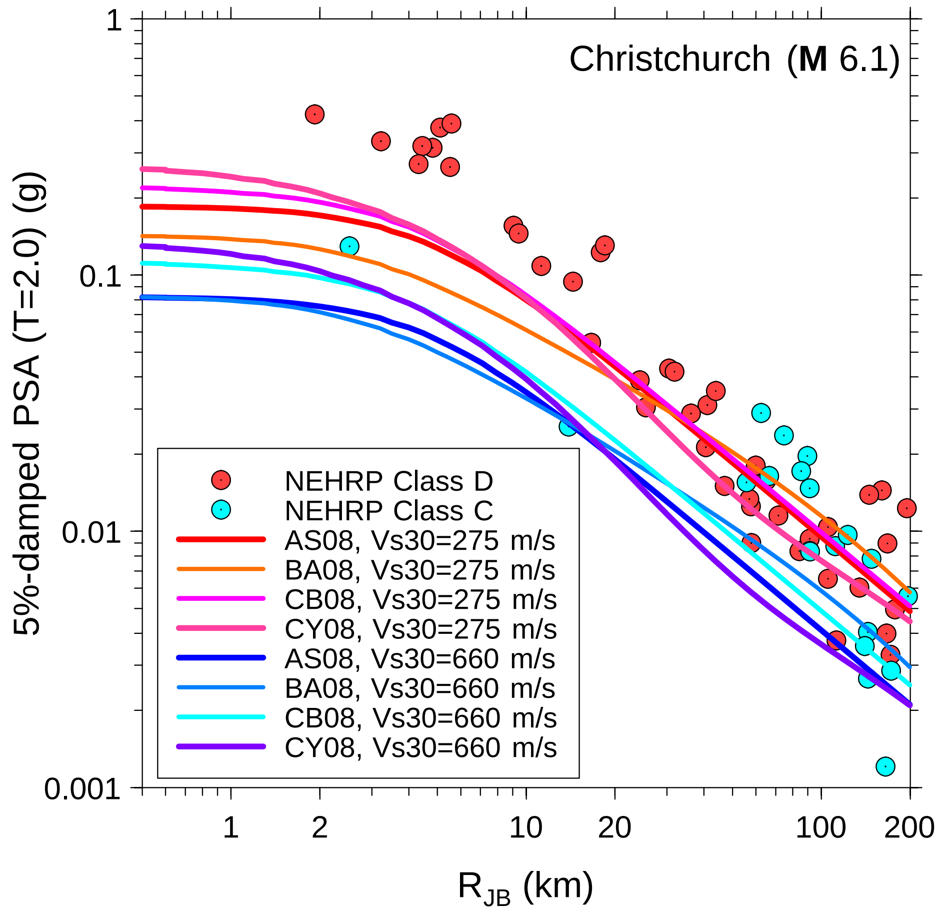
CB08, Vs30=660 m/s
CY08, Vs30=660 m/s


Christchurch (**M** 6.1)
PGA (g)
1
0.1
0.01
1
2
10
20
100
200
RJB (km)
NEHRP Class D
NEHRP Class C
AS08, Vs30=275 m/s
BA08, Vs30=275 m/s
CB08, Vs30=275 m/s
CY08, Vs30=275 m/s
AS08, Vs30=660 m/s
BA08, Vs30=660 m/s
CB08, Vs30=660 m/s
CY08, Vs30=660 m/s


Christchurch (M 6.1)
5%-damped PSA (T=2.0) (g)
1
0.1
0.01
0.001
1
2
10
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100
200
R_JB (km)
NEHRP Class D
NEHRP Class C
AS08, Vs30=275 m/s
BA08, Vs30=275 m/s
CB08, Vs30=275 m/s
CY08, Vs30=275 m/s
AS08, Vs30=660 m/s
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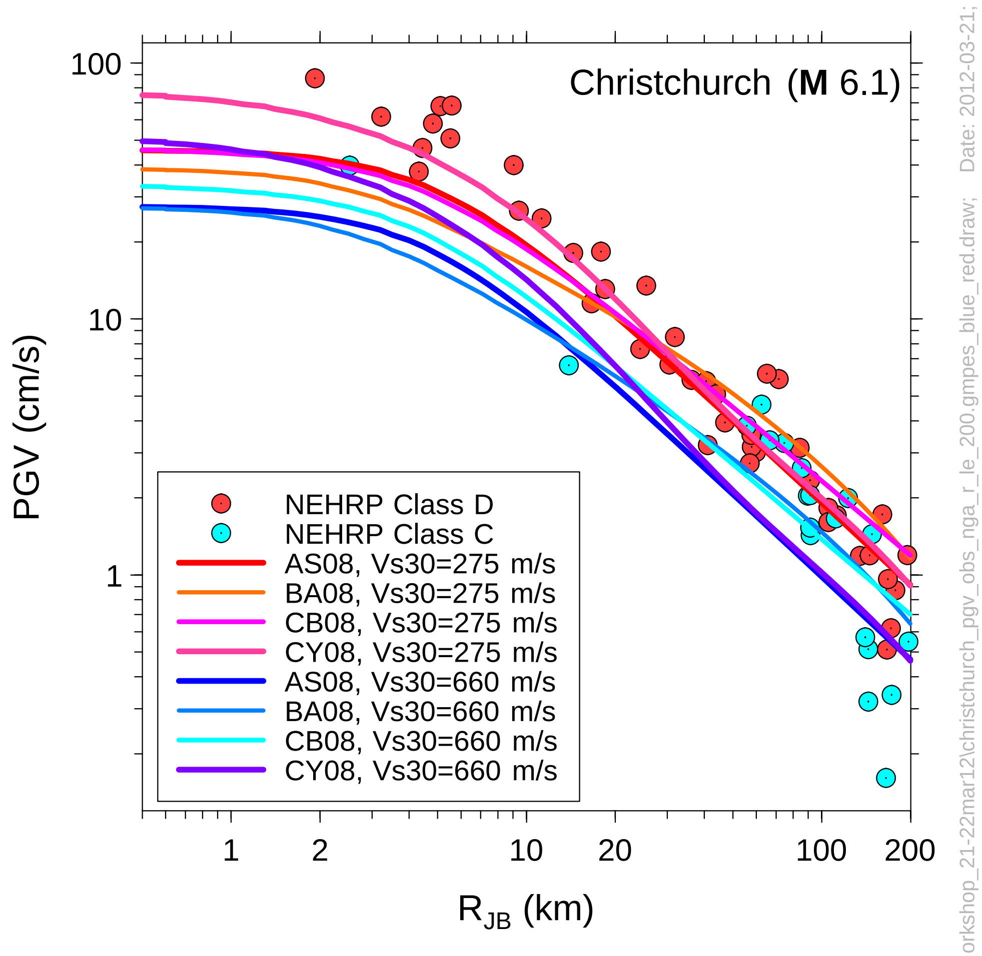
CB08, Vs30=660 m/s
CY08, Vs30=660 m/s


Christchurch (**M** 6.1)
PGV (cm/s)
R_{JB} (km)
100
10
1
1
2
10
20
100
200
NEHRP Class D
NEHRP Class C
AS08, Vs30=275 m/s
BA08, Vs30=275 m/s
CB08, Vs30=275 m/s
CY08, Vs30=275 m/s
AS08, Vs30=660 m/s
BA08, Vs30=660 m/s
CB08, Vs30=660 m/s
CY08, Vs30=660 m/s
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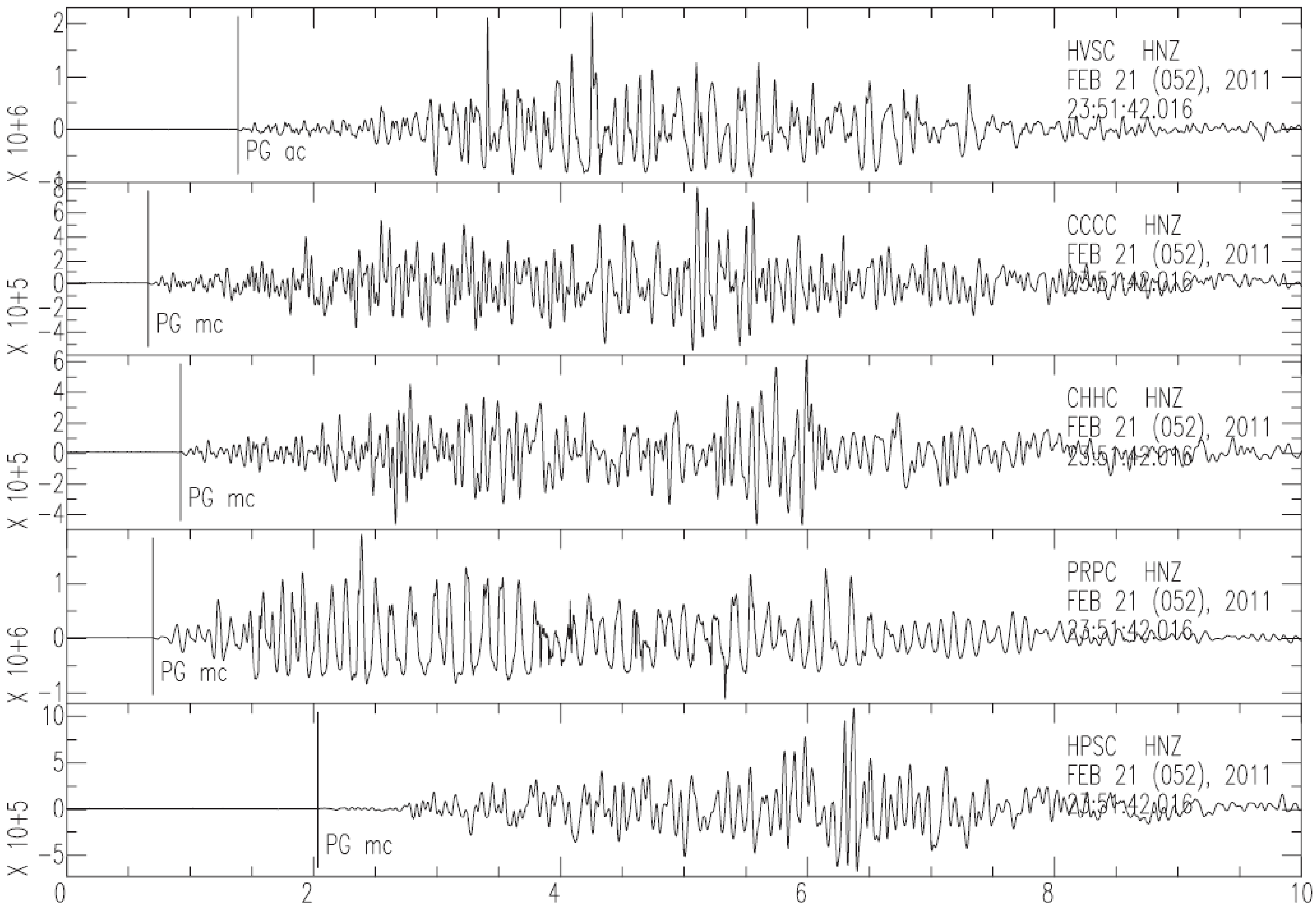

(Fry et al., 2011)