Prediction of Earthquake Ground Motions in Western Alberta

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SUMMARY

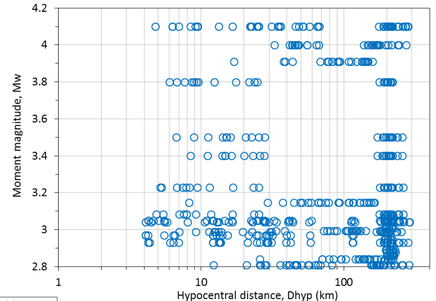
We develop a suite of ground-motion prediction equations (GMPEs) for earthquakes in western Alberta, where seismic hazard contributions from induced events is of particular interest. The available ground-motion data is limited for deriving a robust predictive model in the magnitude range of engineering interest (M>4). We adopt two alternative published predictive models in order to ensure seismologically-informed predictions for moderate-to-large magnitudes. We determine model adjustments for the regional source and attenuation attributes for each model using the referenced empirical approach (Atkinson, 2008). We provide two alternative GMPEs that are fully-adjusted for observed motions in western Alberta and is applicable for wide ranges of magnitude and distance.

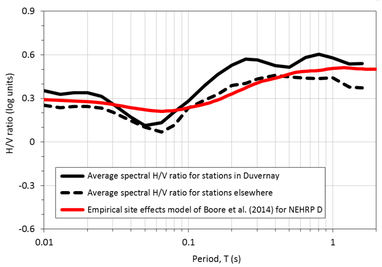
Ground-Motion Data

Earthquakes from September 2013 to February 2016 in western Alberta are compiled from local and regional networks with the following criteria:

- magnitudes $M_w \geq 2.8$
- 3 or more recordings < 300 km

A total of 25 events, most of which is from Duvernay region, are used in the study.





Average spectral H/V ratios for stations in Duvernay and elsewhere in western Alberta are consistent with the site effect model of Boore et al. (2014) for NEHRP D sites (V_{S30}=250m/s).

Host GMPEs

Atkinson (2015): $\log Y_{A15} = c_0 + c_1 \mathrm{M_w} + c_2 \mathrm{M_w}^2 + c_3 log R$

- developed for small-to-moderate events (3<M_w<6) at short distances (<50km), using California motions corrected to the NEHRP B/C reference site condition (V_{S30}=760m/s).

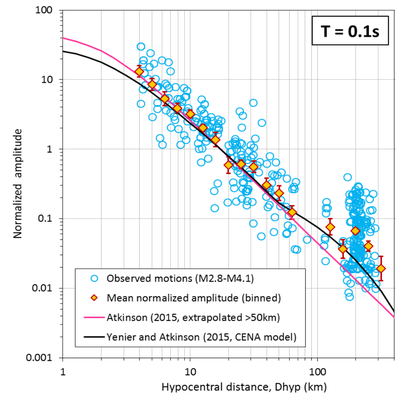
Yenier and Atkinson (2015): $\ln Y_{YA15} = F_M + F_{\Delta\sigma} + F_Z + F_\gamma + \mathrm{C}$

- a simulation-based generic model applicable to wide magnitude (3<M_w<8) and distance (up to 600km) ranges, referenced at NEHRP B/C site condition.
- regionally adjustable stress adjustment ($F_{\Delta\sigma}$), geometrical spreading (F_Z) and anleastic attenuation (F_γ) functions.

Attenuation Attributes in Western Alberta

We assess the decay of ground motion amplitudes with distance in order to gain preliminary insight on the regional attenuation attributes. To effectively remove the differences in source effects between events:

1) Identify a reference distance range within which ground motions from different events overlap most.
2) Calculate the geometric mean of amplitudes for each event at the reference distance bin.
3) Normalize observed amplitudes from each event by the mean amplitude calculated at the reference distance bin for the associated event.

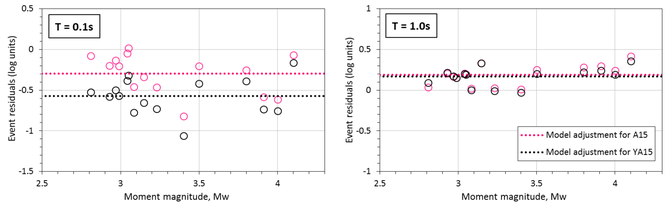


Empirical Adjustment of Host GMPEs

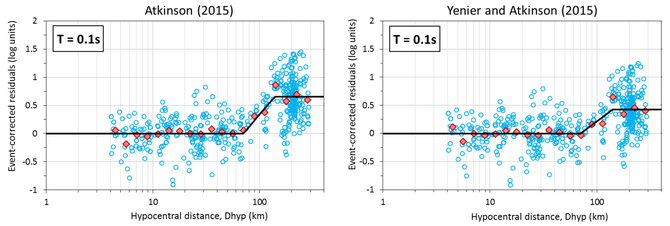
Simple adjustments to well-defined host GMPEs are made by the examination of residuals, for ground motions in western Alberta.

Average residuals calculated for each event using stations within the first 50km; include effects of:

i. differences in average stress between western Alberta and the regions for which the host GMPEs were developed;
ii. differences between average site effects in western Alberta and NEHPR B/C site condition at which the host GMPEs were referenced;
iii. all other residual source effects that are missing/different in the host GMPEs.

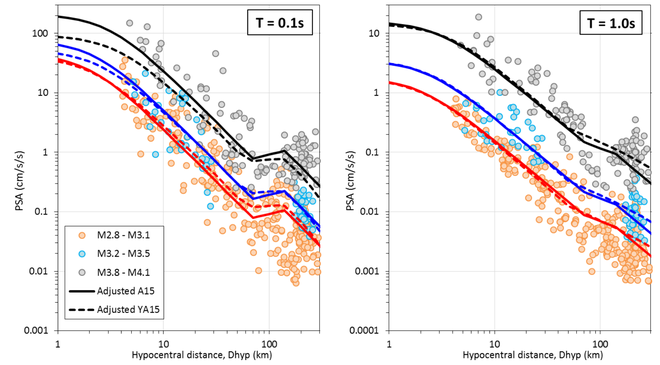


Far-distance (>50km) attenuation adjustment based on inspection of the event-corrected residuals with distance:



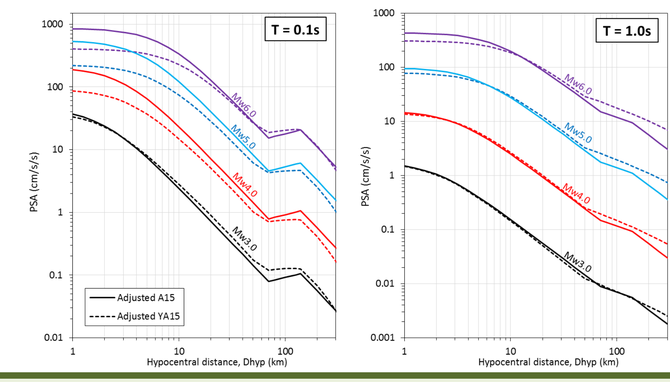
Comparison of Adjusted Models with Empirical Data

Both adjusted models agree well with the observed ground motions in western Alberta. However, the adjusted Atkinson (2015) model performs better for larger events observed in the region.



Conclusions

Two alternative GMPEs are adjusted for the source, attenuation and site attributes observed in western Alberta, using the referenced empirical approach. The adjusted models are similar for small magnitudes where empirical data are abundant. However, they show differences for moderate-to-large events (M>4), reflecting epistemic uncertainty in ground motion prediction, which is an important consideration in seismic hazard analysis.



REFERENCES

Atkinson, G. M. (2008). Ground motion prediction equations for eastern North America from a referenced empirical approach: Implications for epistemic uncertainty, *Bull. Seismol. Soc. Am.* 98, 1304–1318.

Atkinson, G. M. (2015). Ground-motion prediction equation for small-to-moderate events at short hypocentral distances, with application to induced seismicity hazards, *Bull. Seismol. Soc. Am.* 105, 981–992.

Boore, D. M., J. P. Stewart, E. Seyhan, and G. M. Atkinson (2014). NGA-West2 equations for predicting response spectral accelerations for shallow crustal earthquakes, *Earthquake Spectra*, 30, 1057-1085.

Yenier, E., and G. M. Atkinson (2015). Regionally-adjustable generic ground-motion prediction equation based on equivalent point-source simulations: application to central and eastern North America, *Bull. Seismol. Soc. Am.* 105, 1435–1455.