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PREDICTION OF GROUND-MOTION AT HARD-ROCK SITES

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Empirical GMPEs are a useful tool when we are able to input all knowledge of the study site to hand. However, we must often use adjustment factors to avoid biased predictions when our knowledge exceeds their modelling capacity. One such example is the consideration of site-specific hazard. In such cases the target site is typically well studied, with numerous velocity profiles and corresponding linear and non-linear amplification functions available. GMPEs are therefore used to predict ground-motion at the bedrock or reference hard-rock level, with anelastic amplification applied subsequently. Unfortunately however, current GMPEs do not perform well for hard-rock sites, since limited data is available to control their behaviour. Furthermore, current models do not properly account for differences in local attenuation [κ, (Anderson and Hough, 1984)] which must be accounted for when estimating ground motion at hard rock sites.

Due to the primarily non-physical basis of empirical models and the lossy and non-linear operation to obtain response spectra, adjustment of GMPEs, for example to site-specific references, is complicated. Typically, they are adjusted through response spectra consistent Fourier models (Scherbaum *et al.*, 2006, Al Atik *et al.*, 2014): such approaches are, however, highly non-unique. As an alternative to empirical GMPEs, Random Vibration Theory (RVT) simulation models may be used to estimate ground-motion. Physical based adjustments then reduce the epistemic uncertainty of final region specific models (Bora *et al.*, 2013). There is much debate as to the validity of this approach however, particularly at shaking levels of engineering interest.

We present a study exploring the prediction of ground-motion at hard rock sites in Japan: a small and unique subset of sites for which we know more than a typical GMPE can accommodate (e.g. site-specific amplification, attenuation). Initial comparisons of the dataset (including low Vs30 sites) indicated that the Zhao et al. (2006) median prediction performs as expected, with no average bias in either magnitude or distance over a range of frequencies. The variance of the residual misfit was also consistent with that reported by (Rodriguez-Marek *et al.*, 2011). However, subsequent selection of 46 hard rock sites indicated unsatisfactory performance (Figure 1a). Correction of the dataset to the bedrock level through deconvolution of the theoretical SH-transfer function led to even worse bias in the misfit (Figure 1b). We found that we were unable to account for this misfit by applying the response spectra adjustment approach of Al Atik et al. (2014) when considering realistic host-to-target adjustment scenarios (Figure 2).

By adjusting an existing RVT model (Edwards and Fäh, 2013) for regional attenuation in Japan, we were able to improve on the misfit performance by up to 13% over the complete dataset compared to the model of Zhao et al. (2006) by utilizing all available site-specific amplification and attenuation estimates. The reduction in misfit could be isolated to the site (within-event) uncertainty term (Φ), whilst the between-event uncertainty (τ) was similar for the simulation and empirical approaches. Furthermore, upon inspection of the hard-rock sites (Vs30>800m/s), we found significantly better performance using the RVT approach (Figure 1c).

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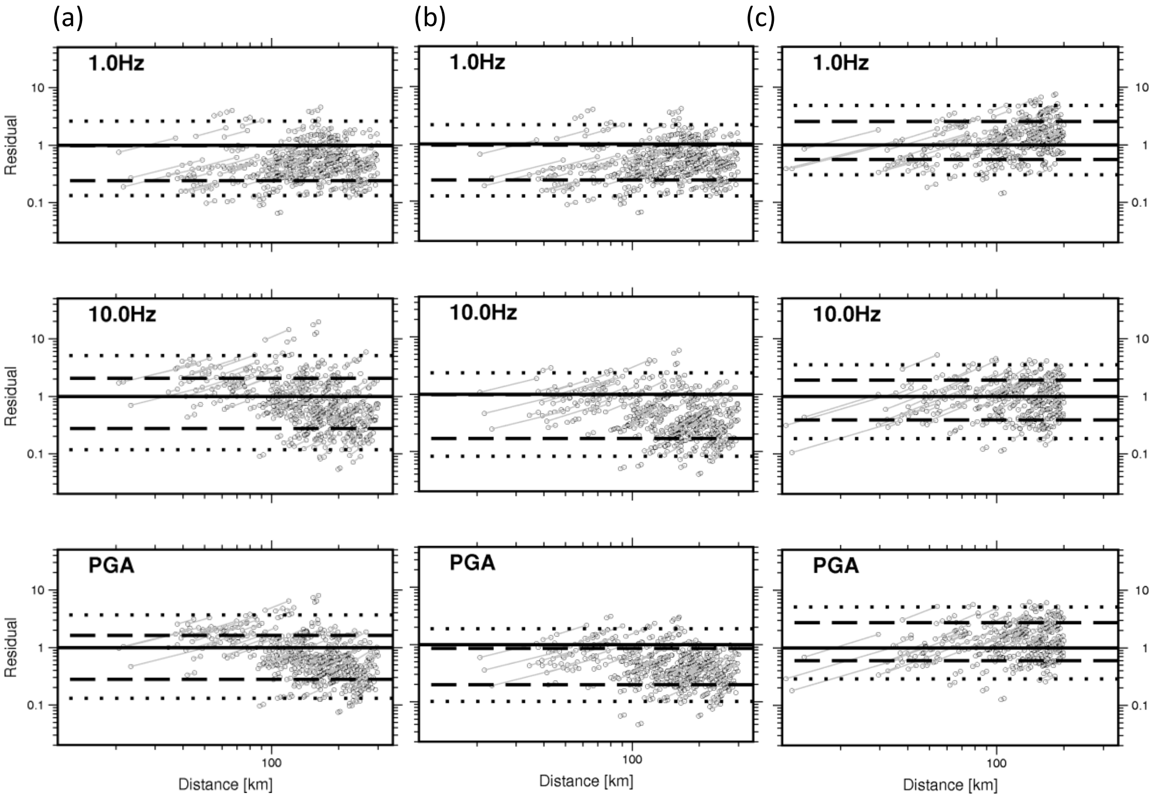

Figure 1: Residual misfit versus rupture distance for 46 sites with Vs30 > 800m/s for (a, b) the model of Zhao et al. (2006) and (c) an RVT model. Lines join upper and lower bounds of R_{rup} for a single recording. The dashed lines indicate the average distribution of 68% of the data, the dotted lines 95%. (a) Original spectra (Vs30 > 800m/s); (b) corrected for elastic SH-amplification to the local bedrock; (c) corrected to a reference rock with Vs30=1350m/s.

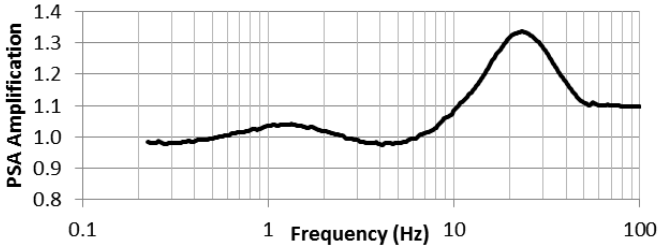

Figure 2: Amplification of PSA between a rock site with Vs30=700m/s (κ=0.035s) and one with Vs30=1350m/s (κ=0.023s) according to the inverse RVT method (Al Atik et al., 2014).

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