REGIONALIZATION OF GLOBAL GROUND MOTION PREDICTION MODELS: TURKEY EXAMPLE

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A large number of global and regional ground motion prediction equations (GMPEs) were developed in the last 20 years that are applicable to shallow crustal and active tectonic regions. Constructing the GMPE logic tree for probabilistic seismic hazard assessment (PSHA) applications is a controversial issue since: (i) local GMPEs are developed from the regional datasets so they are expected to reflect the regional tectonic characteristics better than the others, (ii) the uncertainties introduced by local GMPEs are higher than those of the global GMPEs because they are based on statistically less stable and limited datasets. The objective of this study is to introduce another alternative to local and global GMPEs by regionalizing the global GMPEs that are developed for the same tectonic region as the target area.

Our study is inspired by the work of Scasserra et al. (2009) on the Italian strong motion database (ITACA); however, a much larger dataset including the ground motions recorded from the earthquakes that occurred in Turkey in the last 50 years is used. A compilation of the Turkish earthquakes and strong motion data from the last 50 years was completed as part of the Turkish Strong Motion Database (TSMD) Project (Akkar et al., 2010). This expanded data set of Turkish ground motions is used in this study to evaluate, and modify as needed, the NGA-W1 models for applicability to Turkey. TSMD database is used as the preliminary dataset, however, many parameters required for the NGA-W1 models were missing and had to be estimated. Additionally, we screened the ground motion waveforms for data quality, and calculated the orientation-independent intensity measures.

Using the random-effects regression with a constant term, model residuals between the actual strong motion data and NGA-W1 model predictions are calculated for a period range of 0.01-10 seconds. Incompatibilities between the NGA-W1 GMPEs and Turkish strong motion dataset in small-to-moderate magnitude scaling, large distance scaling and site effects scaling were encountered during the evaluation of the residuals. Event terms indicated a significant overestimation of the ground motions by all 5 NGA-W1 GMPEs, especially for small-to-moderate magnitude earthquakes. An example plot of total-inter event residuals for PGA is shown in Figure 1(a) for Abrahamson and Silva (2008) model (herein AS08 for brevity). Intra-event residuals relative to distance plots suggested no trend within the applicability range of the NGA-W1 models for other tectonic regions. Models including the aftershocks under-predicted the ground motions in the comparison dataset at stiff soil/engineering rock sites. Figure 1(b) and 1(c) show the distribution of the intra-event residuals of AS08 model with respect to rupture distance and average shear wave velocity at the first 30 meters (V_{S30}). Residuals are presented by grey dots in each figure.

These features are systematically modified for all NGA-W1 GMPEs by introducing carefully designed adjustment functions to keep the better-constrained features of the NGA-W1 GMPEs while reflecting the regional ground motion characteristics. We have only modified the small-to-moderate magnitude scaling of the NGA-W1 GMPEs in order to preserve the well-constrained large magnitude scaling of the global dataset. No trends in the residuals are observed in the intra-event residuals vs. rupture distance plots up to 100 kilometers; therefore, the distance scaling of the NGA-W1 models is

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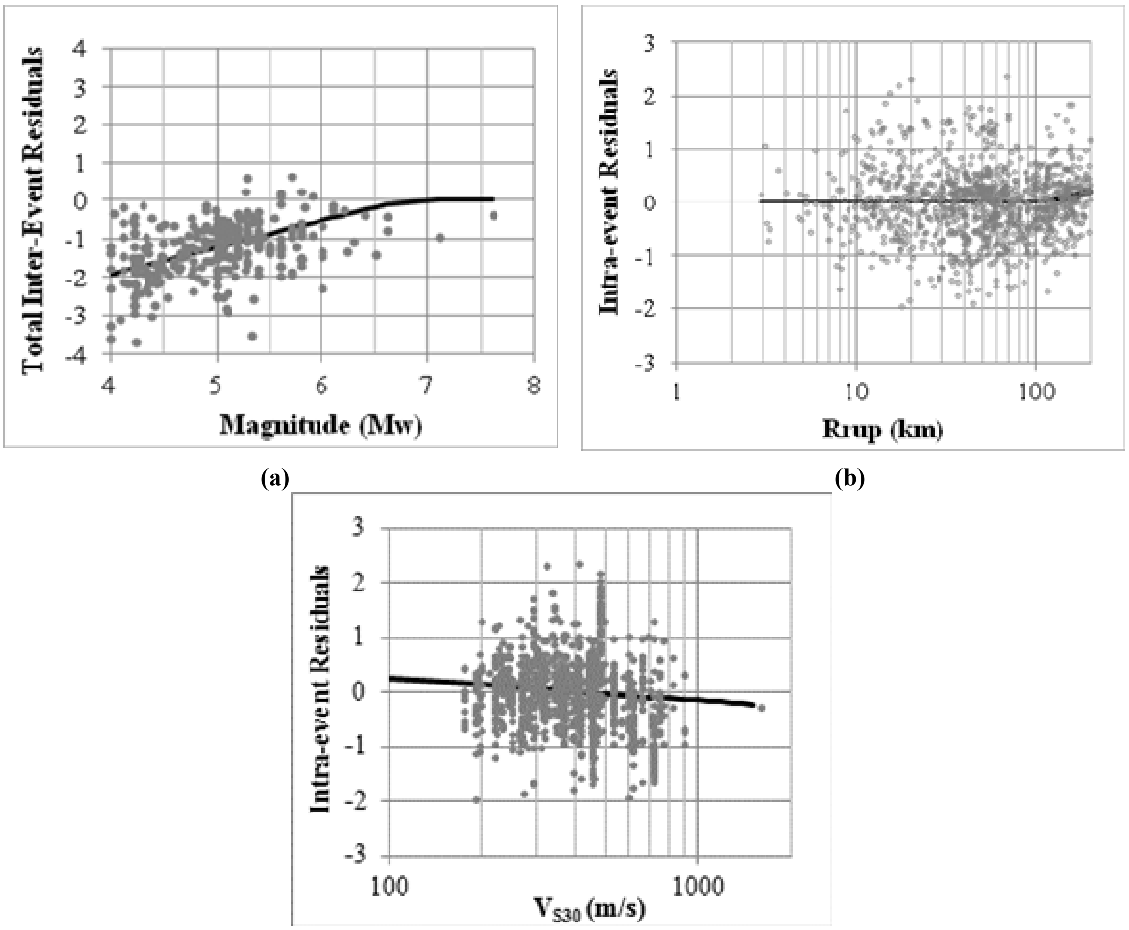
not adjusted. The large distance scaling (between 100 and 200 km) of the AS08 and Chiou and Youngs (2008) (CY08) models with separate gamma terms are modified. The adjustment functions are presented in Figure 1 by the black lines. After the adjustments, the model residuals are re-calculated using the modified forms of the NGA-W1 models and the residuals are re-evaluated for any bias (Gülerce et al., 2014). Median predictions for scenarios important for engineering applications (large magnitude and short distance) after the adjustments were almost identical to the median predictions of the original GMPEs. Even if the median predictions for large magnitudes at short distances remained unchanged, the constant bias in the model predictions was removed after the adjustments.

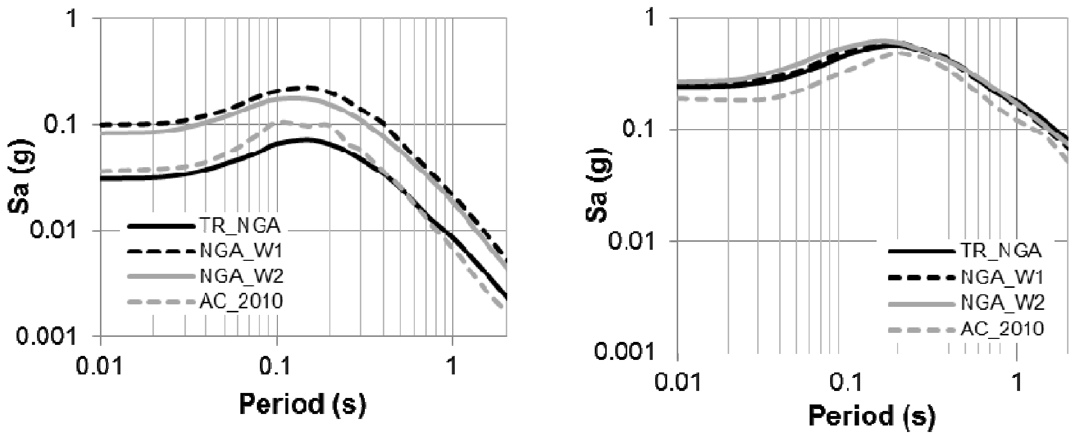


(a) **(b)**

(c)

Figure 1. (a) Distribution of the total-inter event residuals of AS08 model for PGA, distribution of intra-event residuals of AS08 model for PGA with respect to (b) rupture distance, and (c) V_{S30} (also provided in Gülerce et al., 2004)

The average median response spectra of the NGA-W1 models (broken black lines) and Turkey-Adjusted NGA-W1 models (solid black lines) are compared for different scenarios in Figure 2. Median predictions of NGA-W2 models are also provided in Figure 2 (gray lines) since some of the issues that required adjustments (small magnitude scaling, regionalization of the V_{S30} and large distance terms) were included in the updated NGA-W2 GMPEs. Median predictions of Akkar and Çağnan (2010) (AC10) model, a regional model that was developed using a subset of the same database (TSMD, Akkar et al, 2010), is also added to the comparison plots, because agreement of the median predictions for the range well-constrained by the Turkish dataset (M4 to M6) is expected (broken gray lines). Figures 2(a) and (b) show the median predictions for magnitude 5 and magnitude 7 strike-slip earthquakes at the rupture distance of 10 kilometers for average rock (V_{S30}=760 m/s) conditions, respectively.



(a) **(b)**

Figure 2. Median predictions of NGA-W1, NGA-W2, TR-Adjusted NGA_W1 and Akkar and Çağnan (2010) models for; (a) M5, D10km, V_{S30}=760 m/s, (b) M7, D10km, V_{S30}=760 m/s.

For the small magnitude scenario provided in Figure 2(a), predictions of the TR-adjusted models and AC10 model are very similar indicating that the small-to-moderate magnitude scaling of the Turkish ground motions are captured by the magnitude adjustment function. However, the TR-Adjusted NGA-W1 models are significantly lower than the NGA-W1 and NGA-W2 models. The median predictions of the TR-Adjusted models are only slightly different from the NGA-W1 and NGA-W2 models for large magnitude earthquakes due to the effect of linear site amplification scaling adjustment (Figure 2(b)). A significant difference between the other models and AC10 is observed in Figure 2(b); predictions of the TR-adjusted NGA-W1 models are very close to the predictions of global models for large magnitudes, but significantly higher than the predictions AC10 model.

We believe that the new set of Turkey-Adjusted NGA-W1 models proposed in this study is suitable for ground motion characterization studies in Turkey.Some important pieces of the NGA-W1 GMPEs such as the style of faulting and hanging wall effects could not be evaluated since the majority (65-70%) of the events in the Turkish database consists of strike slip earthquakes. Also, the non-linear site response effects incorporated in the models are adopted without a change. These features may be tested in the future once the dataset is enriched by dip-slip mechanism events and site-response simulation results representative of the deeper shear-wave profiles of the recording stations in Turkey are available. A standard deviation model for the ground motions in the Turkish dataset that acknowledges the repeatable path effects is under development. We recommend the use of standard deviations of the original NGA-W1 models until the single-station sigma model of Turkey is developed.

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