Dependency of near-field ground motions on the structural maturity of the North-Anatolian Fault Zone

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Summary

Most of the ground motion prediction equations are based on understanding the site-specific influences on recorded ground-motions and just a few studies are analyzing source-specific influences, like the fault maturity, Manighetti et al.(2007), Radiguet et al. (2009), Bohnhoff et al.(2016).
This study empirically examines the potential influence of the structural maturity on recorded near-field ground motions specifically for the North-Anatolian-Fault Zone (NAFZ) by analyzing ground motion recordings for shallow crustal earthquakes with magnitudes between 4.0 - 7.6 Mw and different style-of-faulting. The structural maturity of the fault zone is classified into three parts(the eastern mature part, the central intermediate, and the western immature part) according to the parameters of age, slip-rate, cumulative slip and the length of the fault, Manighetti et al.(2007), Radiguet et al. (2009).
We compared the recorded ground motions to three given pan-European GMPEs to find the best fitting model for the fault zone. To see if regional variations are present, we determined the peak-ground-acceleration (PGA) residuals and response spectral acceleration (SA) for different periods. Consequently our results show that recordings from the mature part of the fault zone show lower amplitudes in the ground motions. Furthermore the chosen reference models show large misfit for the mature part of the fault zone. Therefore we conclude that the maturity strongly affect recorded ground motions and should be included in future ground-motion prediction equations.

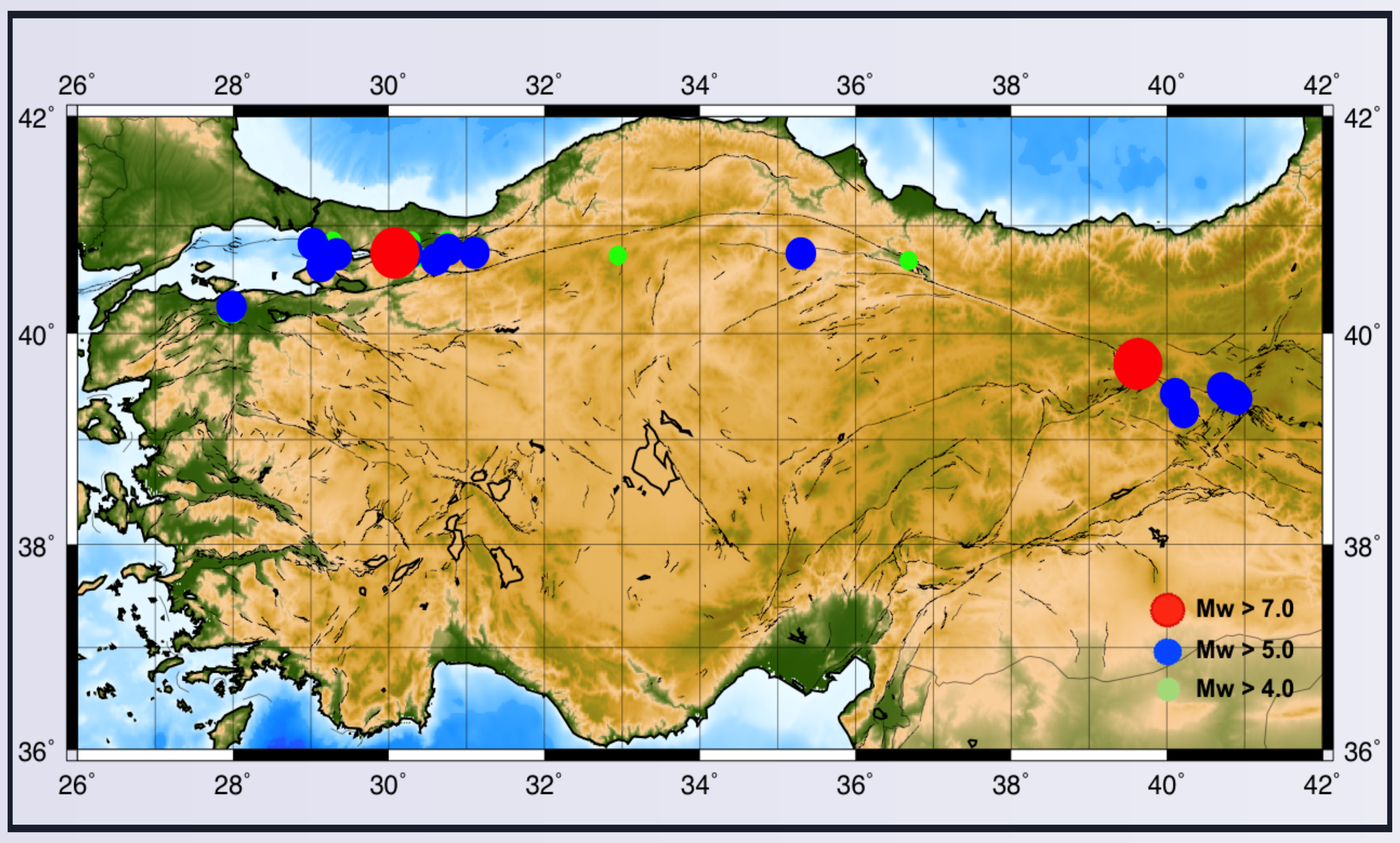

Figure 1: Earthquakes along the North-Anatolian Fault Zone used in this study. The maximum distance from the fault was set to 20km, therefore all recordings gathered are near-field.

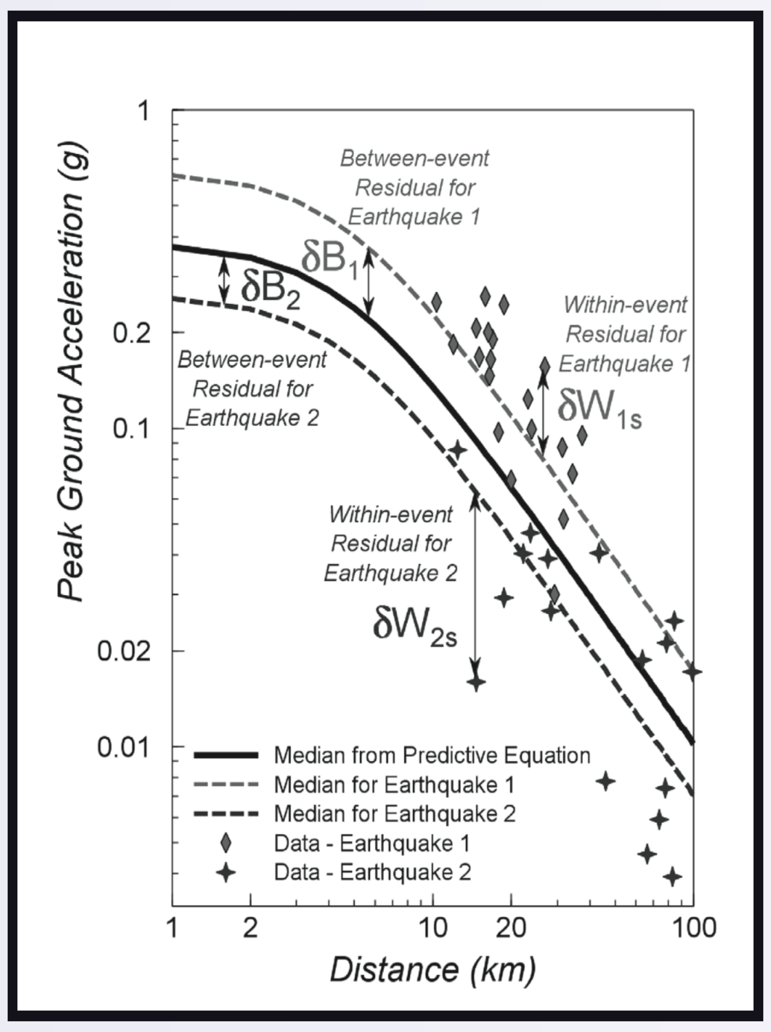

Figure 2: Between and within event components. Figure taken from Strasser et al. (2009)

Source-specific analysis

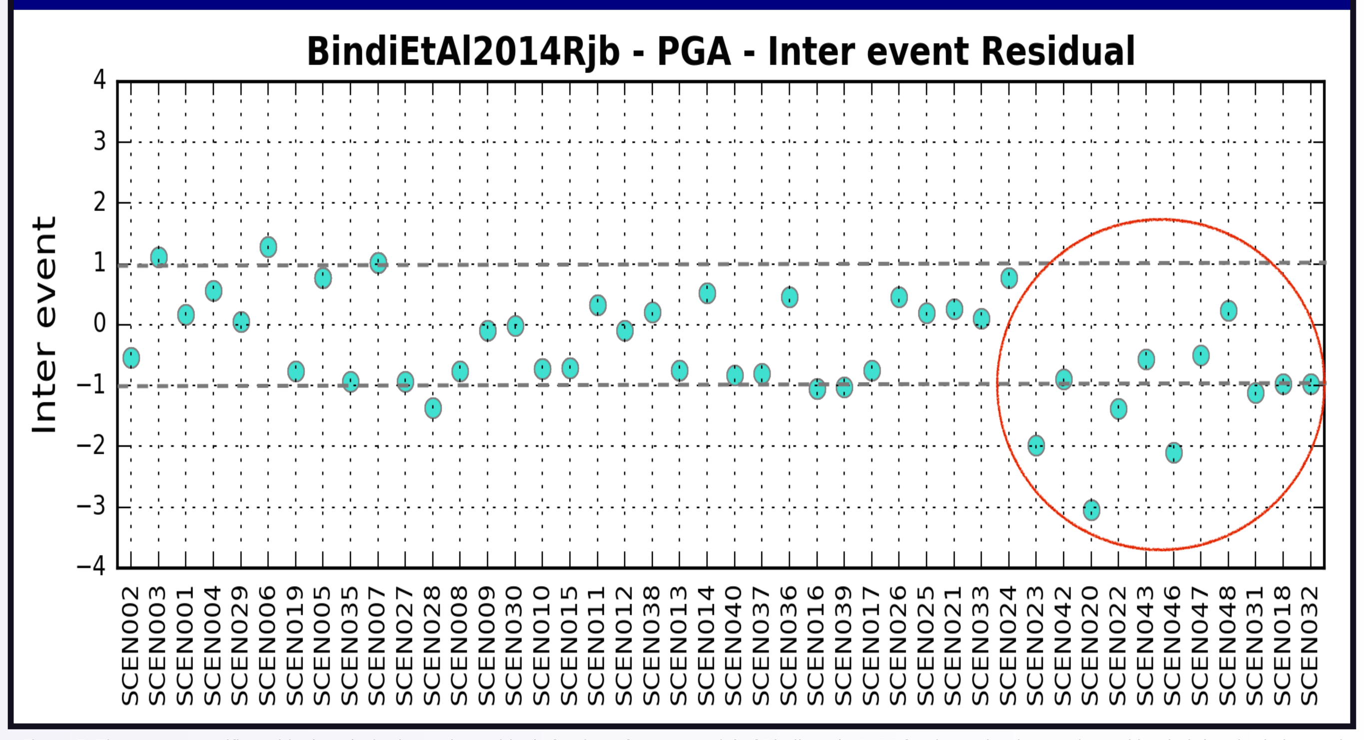

Figure 7: The source-specific residual analysis shows the residuals for the reference model of Bindi et al., 2014 for the entire dataset (sorted by their longitude increasing from west to east).The red circle shows the residuals only for the mature part, which are out of range with respect to the ground motion model.

Data & Methods

Using the strong ground motion database of Turkey (AFAD) we analyzed 249 near-field ground motions gathered from 42 earthquakes whereby all events are shallow (max. depth 20km) so that the depth dependency has been ignored. Proposed by Manighetti et al. (2007) and Bohnhoff et al. (2016) we classified the NAFZ into three different parts, mature (13Ma), intermediate (7-8 Ma) and immature (2-3Ma). According to Cotton et al. (2006) we rejected GMPE's which didn't fit to the selection criteria thus reduced the reference models to three pan-European equations: Akkar & Bommer (2010), Akkar et al. (2014) and Bindi et al.(2014). The PGA and SA residuals have been calculated as the difference between the normal distribution of the model and the recorded data (Figure 3-6). We further calculated the total, between and within event residuals (Fig.6&7) to analyze in detail the source- and site specific influences on the ground motions. To see the impact of local site-effects, we calculated the within-event residuals, which shows the misfit between an individual observation at a station from the earthquake specific median prediction (Al-Atik et al. 2010).

Site-specific analysis

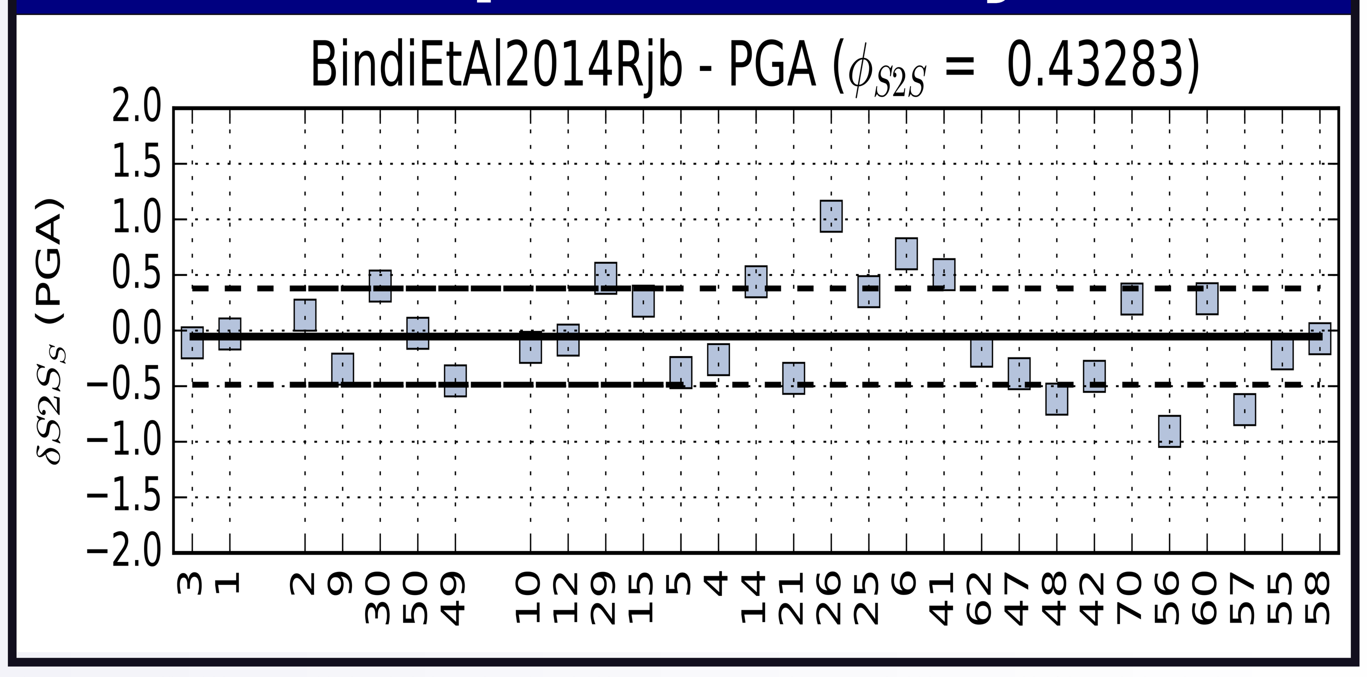

Figure 8: Site-specific within-event residual analysis for each station. The blue squares represent the averaged within-event residual for each site. The sites are sorted by their longitude.Stations until 26 are all located on the immature part of the fault zone.

PGA analysis

Immature part

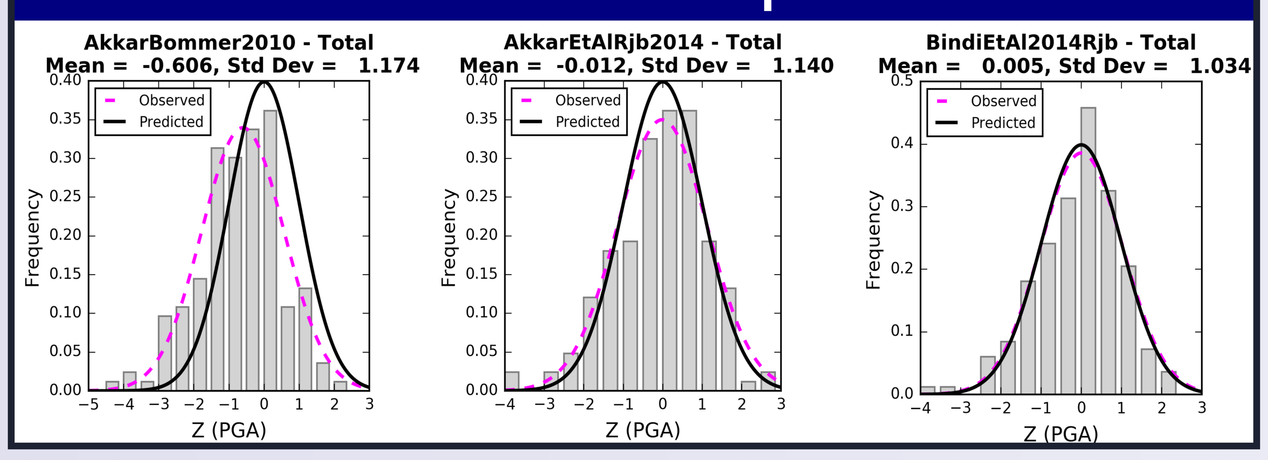

Figure 3: PGA residual dostribution for the immature part of the fault zone. Black curves indicate the expected distribution given by the models and the dashed pink curve show the calculated residuals for the used data in this study.

Mature part

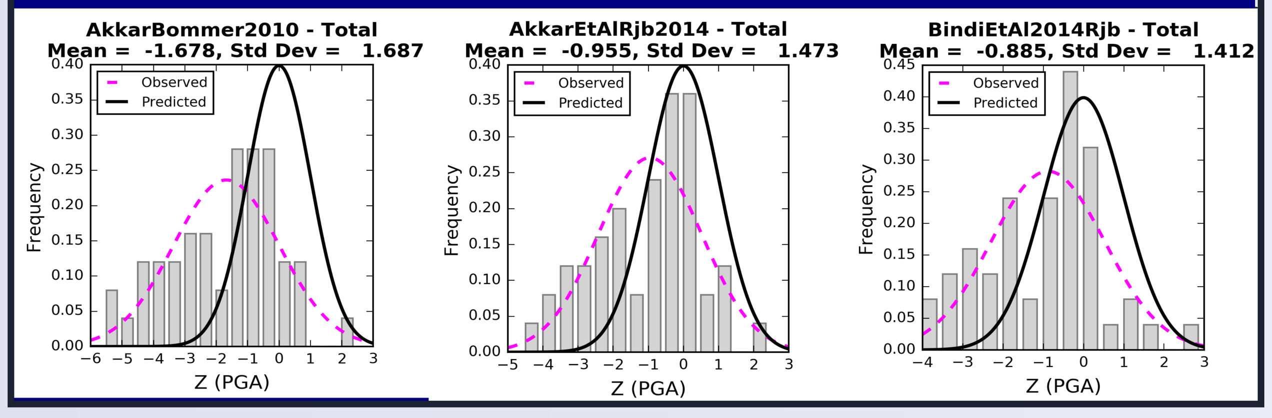

Figure 4: PGA residual distribution for the mature part of the fault zone. A large misfit between the expected values given by the model and the real data can be observed,

SA analysis

Immature part

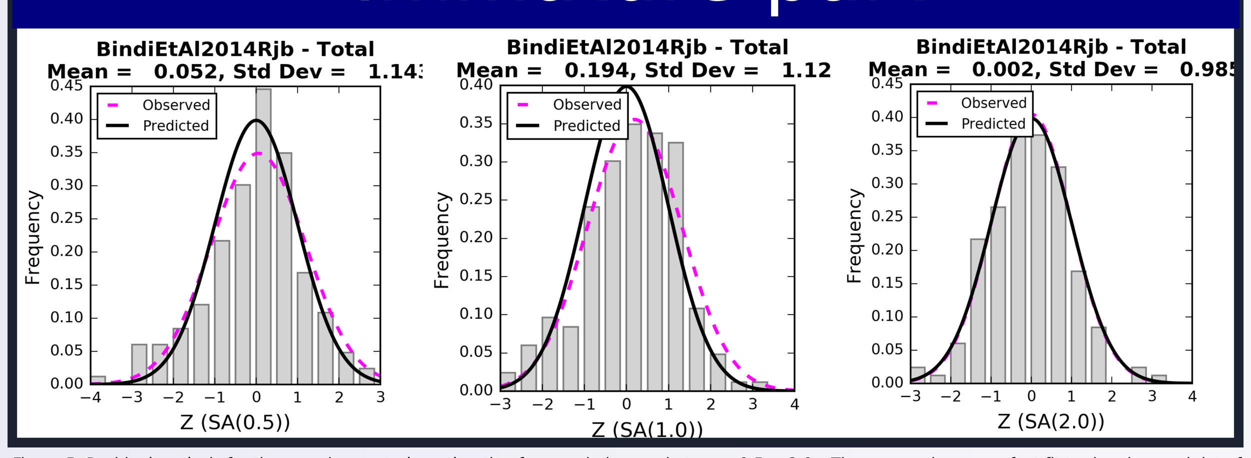

Figure 5: Residual analysis for the pseudo-spectral acceleration for a period range between 0.5s - 2.0s. The curves show a perfect fit to the observed data for a period of 2.0s.

Mature part

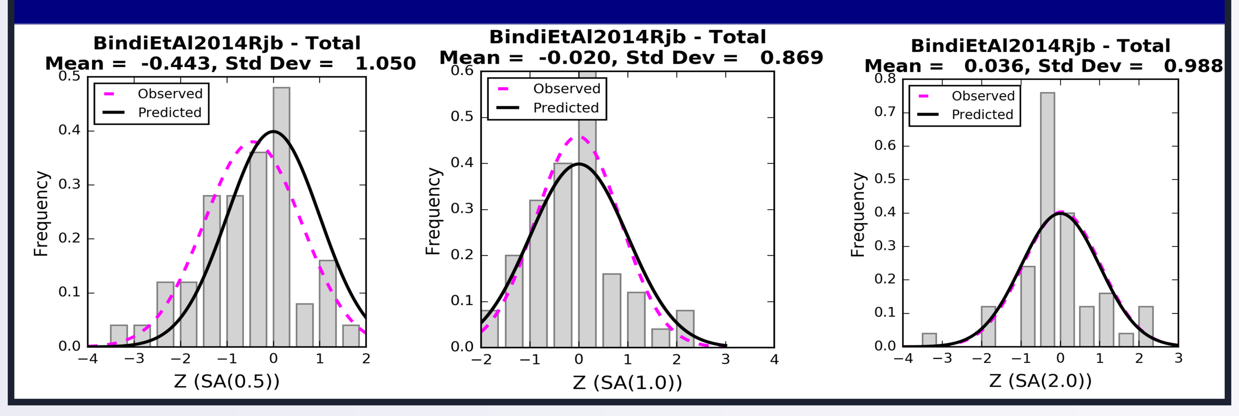

Figure 6: Residual analysis for the mature part of the fault zone for a period range between 0.5s- 2.0s. The curves show larger misfit than for the immature part

References

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- Bohnhoff, Marco, et al. "Maximum earthquake magnitudes along different sections of the North Anatolian fault zone." Tectonophysics 674 (2016): 147-165.
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Results

Our results show that the reference model of Bindi et. al.,2014 is the best fitting amongst others in terms of representing the regional characteristics of the NAFZ. On the other hand, in the residual analysis there is a major misfit on the mature part of the fault zone. Thus our analysis shows that recorded ground motions on the mature part are much lower than those on the immature part.

Furthermore, we calculated the residuals for the spectral acceleration for a period between 0.5s-2s and our results show that the misfit for the residuals is only present until a period of 2s (even for the mature part). For both analyzes, PGA and SA we observed that the reference models do not fit well to the mature part of the fault.
To be sure that the effects of maturity on ground motions are existent, we test the influence of fault maturity on earthquakes with the same style-of-faulting (not presented here). The results were considerably the same so we suggest that the biggest influence on the recorded strong ground motions is the fault structural maturity.It is known that available GMPE's have uncertainties according to each other and that the reason for those uncertainties might be due to the some missing parameters in the GMPE's, such as the fault maturity, which affect the ground motion variability. For future work, we suggest to include additional source-specific parameters such as the fault maturity or fault cumulative offset to reduce the ground motion variability.