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Comparison of Arias Intensity and Duration Prediction Equations for Shallow and Crustal Earthquakes in Japan

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Abstract. The KiK-net ground motion database is used to develop ground motion prediction equations for Arias Intensity (I_a) and 5-95% Significant Duration (Ds_{5-95}). Relationships are developed both for shallow crustal earthquakes and subduction zone earthquakes. The models developed consider site amplification using a simple V_{S30}-based parameterization. For Ds_{5-95}, we also observe strong magnitude dependency in path duration. The results of this study also allow a comparison between earthquakes in shallow-crustal and subduction regimes. This comparison shows that Arias Intensity of shallow crustal earthquakes increases more rapidly with magnitude and Arias Intensity of subduction earthquakes attenuate more with distance. On the other hand, the ground motion prediction equation for duration is different for both types of earthquakes. In general, durations for subduction earthquakes are longer for similar magnitude earthquakes. We observe partial saturation for the duration of subduction earthquakes after 200 km and partial saturation for shallow crustal earthquakes after 50 km. We also investigate the relationship between Arias Intensity and duration residuals. Arias Intensity and duration residuals are negatively correlated which means, on average, when Arias Intensity is over predicted duration is underpredicted.

Keywords. Duration, Arias Intensity, ground motion prediction equation, energy-based parameters.

1. Introduction

The diverse earthquake sources and the large number of recoded ground motions by KiK-net in Japan provide a great opportunity to understand the effect of earthquake tectonic regime on ground motions. In this paper we investigate the effect of tectonic regimes on two energy related parameters, which are significant duration (Ds_{5-95}) and Arias Intensity (I_a). To understand what is the effect of tectonic regime, we compare the estimates of ground motion prediction equations (GMPEs) developed for each tectonic regime and evaluate the differences in predictions.

In this paper we study two energy-related ground motion parameters. The Arias Intensity is a measure of ground motion energy. Therefore, Arias Intensity is expected to correlate well with earthquake induced damage measures that are primarily related to energy rather than with the peak acceleration of ground motions. Based on a review of existing literature, we observe that Arias Intensity of ground motions correlates well with

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earthquake induced landslides and damage to adobe and clay structures ([1], [2], and [3]). Significant duration of a ground motion quantifies the time the energy of an earthquake arrives at a site. Significant duration of an earthquake has several applications in Geotechnical and Structural Engineering. The duration of an earthquake ground motion is used in predicting the response spectra of a ground motion or to generate ground motion time histories based on its Fourier amplitude. Moreover, the duration of ground motion is used in damage evaluation of buildings and liquefaction triggering ([4] and [5]). Therefore, it is important to study the effect of tectonic regimes on these two parameters. The authors of this paper developed GMPEs for Arias Intensity and duration of shallow crustal and subduction earthquakes ([6] and [7]). The results of those studies are used here. In the following paragraphs, we first review the GMPEs for each parameter and then compare the effect of tectonic regime. At the end, we present the estimated correlation between Arias Intensity and Significant Duration.

2. Arias Intensity

In the Arias Intensity GMPE, Bahrampouri et al. [6] used earthquake magnitude (**M**), source to site distance (R_{rup}), and the upper 30 meters average shear wave velocity (V_{S30}) as input parameters. Based on the regression analyses, the Arias Intensity of ground motions are positively correlated with **M** and V_{S30} and negatively correlated with R_{rup}. Figures 1a and Figure 1b show the estimates of Arias Intensity of shallow crustal and subduction earthquakes for different magnitudes and distances. In Figure 1c, we compare the Arias Intensity of shallow crustal and subduction earthquakes by presenting their difference in log domain versus distance for different magnitudes. This comparison shows that the Arias Intensity of shallow crustal earthquakes increases more rapidly when magnitude is increased than that of subduction earthquakes. On the other hand, the Arias Intensity of subduction earthquakes attenuates more rapidly with distance. Note the attenuation of subduction earthquakes is different from shallow crustal earthquakes because the waves produced by these two different types of sources travel through different crustal materials which are likely to have different attenuation rates.

3. Duration

It is common in the development of GMPEs for duration to decompose the duration of a ground motion into source and path durations. Source duration is the duration of an earthquake at zero distance. Path duration is the duration added to the source duration due to source to site distance. Bahrampouri et al [7] followed the same procedure and corrected the duration for site effects. The source duration is positively correlated with magnitude and the path duration of earthquake is linearly correlated with the distance. The slope of path duration versus distance is dependent on magnitude. The duration of a ground motion is negatively correlated with V_{S30} and positively correlated with Z_1. Figures 2a and Figure 2b show the dependence of ground motion duration of shallow crustal earthquakes on distance and magnitude. Figure 2c shows the difference between duration of shallow crustal and subduction earthquakes. Based on this plot duration of subduction earthquakes is higher than duration of shallow crustal earthquakes except for small magnitude earthquakes (less than about M5.5) and a narrow range of distances centered around 60 km.

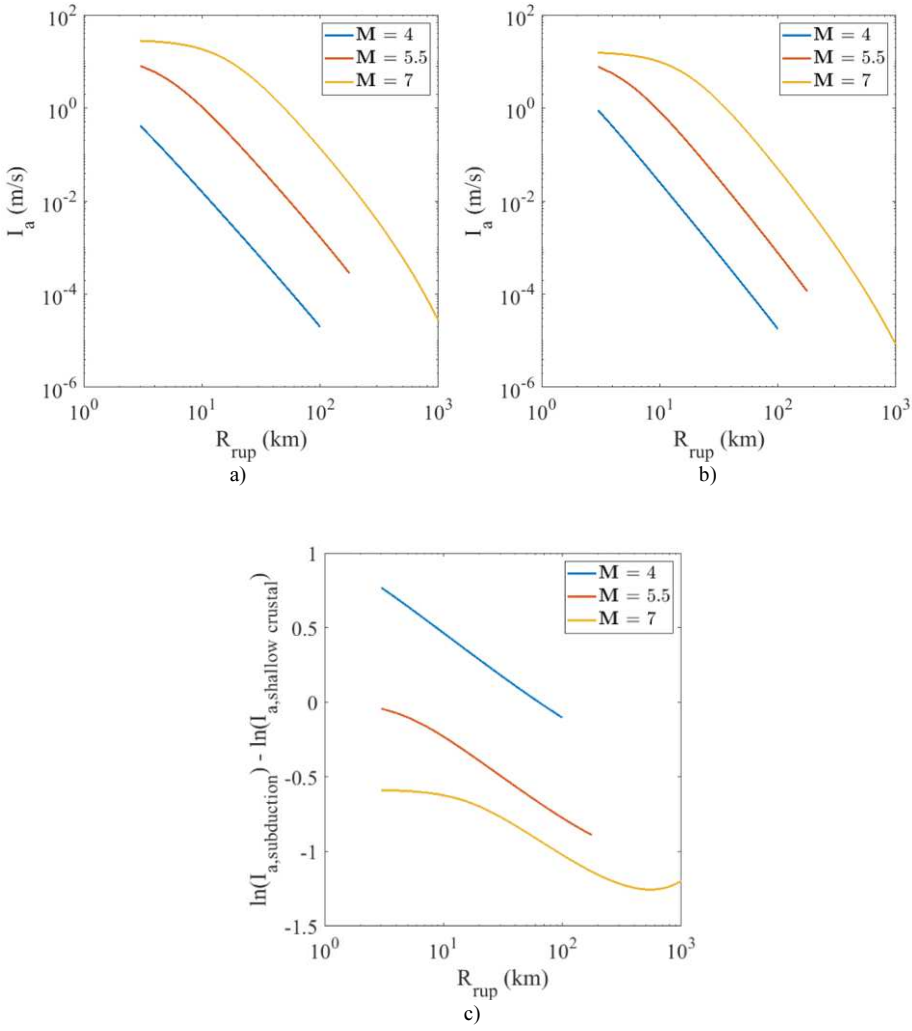

Figure 1. a) estimated Arias Intensity of shallow crustal earthquakes versus distance b) estimated Arias Intensity of subduction earthquakes versus distance b) the difference between subduction and shallow crustal Arias Intensity for different earthquake scenarios.

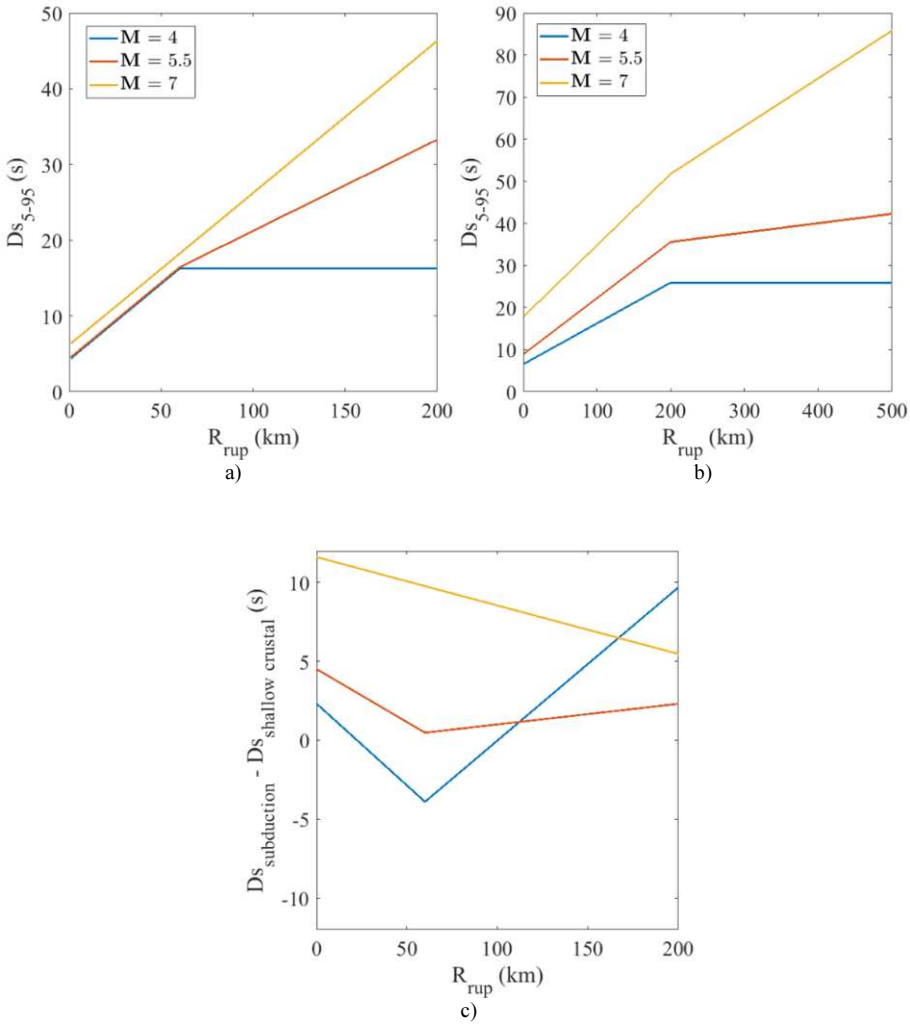

Figure 2. a) estimated duration of shallow crustal earthquakes versus distance b) estimated duration of subduction earthquakes versus distance b) the difference between subduction and shallow crustal duration for different earthquake scenarios.

4. Correlation of Arias Intensity and duration of an earthquake

The correlation between residuals of two intensity measures (i.e., ground motion parameters) is used in vector probabilistic seismic hazard analysis [8]. In Figure 3 we present the correlation between residuals of duration and Arias intensity for shallow crustal earthquakes. Based on these results, Arias Intensity and duration are seen to be negatively correlated with the correlation coefficient of -0.30114. The negative correlation implies that, on average, when Arias intensity is overpredicted the duration is under predicted.

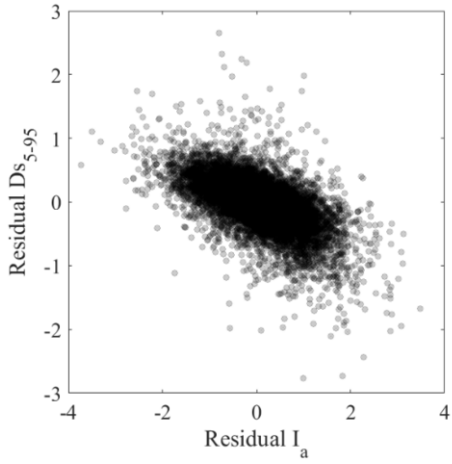

Figure 3. Residuals of duration GMPE versus Arias Intensity GMPE for each recording.

5. Conclusion

In this paper we investigated the effect of tectonic regime on Arias Intensity and duration of earthquakes. The results show that on average:

- The Arias Intensity of subduction earthquakes attenuates more rapidly compared to shallow crustal earthquakes
- The Arias Intensity of subduction earthquakes increases less when magnitude is increased compared to that of shallow crustal earthquakes
- The duration of subduction earthquakes is longer than that of crustal earthquakes.

Moreover, Arias Intensity and duration are negatively correlated with a correlation coefficient of - 0.31.

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