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# PRELIMINARY NGA-SUBDUCTION GLOBAL GROUND MOTION MODEL WITH REGIONAL ADJUSTMENT FACTORS

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## ABSTRACT

The NGA-Subduction Project is a multi-year, multidisciplinary project with the goal of developing a ground motion database and ground motion models for global subduction zone earthquakes including those in Japan, Taiwan, Cascadia, Alaska, New Zealand, South America, and Central America. Our ground motion model development is currently at the stage of identifying regional trends in path terms. We use a combination of data inspection and regression techniques to distinguish path effects in the data, including differences between interface and in-slab events, forearc/back-arc effects, regional effects, and azimuthal effects. Our approach to model development is to first develop a path model capturing these effects, then to investigate source and site effects. The parameterization of functional form is guided in part by the scaling expected by a generic equivalent point-source stochastic model. We expect regionalization in path and will investigate further regionalization in site response and in overall model bias.

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# Preliminary NGA-Subduction Global Ground Motion Model with Regional Adjustment Factors

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## ABSTRACT

The NGA-Subduction Project is a multi-year, multidisciplinary project with the goal of developing a ground motion database and suite of ground motion models for global subduction zones encompassing those in Japan, Taiwan, Cascadia, Alaska, New Zealand, South America, and Central America. Our ground motion model development is currently at the stage of identifying regional trends in path terms. We use a combination of data inspection and regression techniques to distinguish path effects in the data, including differences between interface and in-slab events, forearc/back-arc effects, regional effects, and azimuthal effects. Our approach to model development is to first develop a path model capturing these effects, then to investigate source and site effects. The parameterization of a functional form is guided in part by the scaling expected by a generic equivalent point-source stochastic model. We expect regionalization in path and will investigate further regionalization in site response and in overall model bias.

## Introduction

Next Generation Attenuation-Subduction (NGA-Sub) is a large, multidisciplinary, multi-year project with the goal of producing uniformly processed earthquake ground motion data, including time series and spectra, as well as producing a suite of regional and global ground motion models (GMMs) for subduction zone earthquakes. This project is organized by the Pacific Earthquake Engineering Research Center (PEER), and encompasses subduction zones around the world including those in Japan, Taiwan, British Columbia (Canada), Alaska and the Pacific Northwest (United States), New Zealand, Mexico, Chile, and Peru. Currently the project has almost completed the data acquisition and processing phase [1], and the model development phase is ongoing.

This manuscript concerns the development of one of the NGA-Subduction GMMs. Our approach to the development of a GMM using the NGA-Sub database has thus far been heavily focused on the path effects. This has been strategic, as a major challenge in the modeling of

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subduction ground motions is accounting for strong regional variations in path effects, with some areas (such as Chile) having relatively slow distance attenuation for large magnitude events, and others (such as Japan) having relatively fast attenuation. Other complicating factors for a given region are fast attenuation of waves crossing the volcanic front, leading to different trends in the forearc and back-arc regions, and lastly the slow attenuation of waves that propagate within the colder, older subducting slab for much of their path.

In this extended abstract, we present observed trends in ground motions from inspection of the global database, focusing on regional differences in path effects. We describe our initial modeling approach for the path term and source term for peak ground acceleration (PGA), peak ground velocity (PGV), and thirteen 5% damped RotD50 pseudo-spectral acceleration (PSA) oscillator periods between 0.1 and 10s.

## Trends in Global Database

### Database

The NGA-Sub database [1] contains more than 60,000 three-component time series from 740 earthquakes from subduction zone regions around the world. Starting with all available data, we screened based on a number of criteria: (1) All necessary metadata (e.g.  $V_{S30}$ ,  $R_{rup}$ ) are populated for the record; (2) the recording instrument sensor depth is less than 2m deep; (3) the earthquake moment magnitude ( $\mathbf{M}$ ) is 5 or greater; (4) the earthquake is classified as either an interface or inslab event; (5) the rupture distance ( $R_{rup}$ ) is less than the  $R_{max}$  established by the NGA-Sub team or 1000km, whichever is less; (6) the earthquake is a mainshock; (7) the earthquake is not a multi-rupture event; (8) the PSA oscillator period is within the useable bandwidth of the recording; (9) the hypocentral depth is less than 200 km; (10) the earthquake has at least three recordings after criteria (1)-(9) are applied. After application of the above screening criteria, our first step in the modeling process was a lengthy visual inspection process of the data in order to determine global trends in geometric spreading and anelastic attenuation for inslab and interface events, and how these trends varied with magnitude, PSA oscillator period, and region.

### Observed Data Trends

In order to compare trends across all data, we first corrected each recording to a reference velocity condition of 760 m/s using the Seyhan and Stewart (2014) site amplification model, with Boore et al. (2014) used as a predictor of rock PGA [2,3]. We then plotted the data as a function of rupture distance for various regions and moment magnitude ( $\mathbf{M}$ ) bins.

In general, we observe steeper distance attenuation in ground motions from interface events than inslab events. This observation holds true across all regions except Taiwan and some magnitude bins in South America. Additionally, inslab events tend to produce larger ground motions at a given rupture distance than interface events for  $\mathbf{M} > 6$ , with the biggest difference for  $\mathbf{M} = 8$ .

The apparent amplitude decay for interface events is very steep, being close to  $1/R^2$  for Japan, Taiwan, New Zealand, South America, and Central America and Mexico, and even steeper for Cascadia and Alaska. For inslab events, we see a flattening in the apparent amplitude decay as  $\mathbf{M}$  increases for Japan, Taiwan, New Zealand, South America, and Alaska, but do not see a clear

trend in the data from Central America and Mexico or Cascadia. For interface events, the flattening in the distance attenuation slope as  $M$  increases is less clear; we see a trend for Alaska, New Zealand and South America but the other regions have no clear trend. Some of the observed trends can be interpreted in the context of a simple generic point-source model [4], but there are complicating factors that need to be considered for subduction events.

We also see steeper attenuation in back-arc recordings than forearc recordings, consistent with previous studies [5]; this trend is expected due to the increased absorption of energy as the path crosses the volcanic arcs associated with subduction zones.

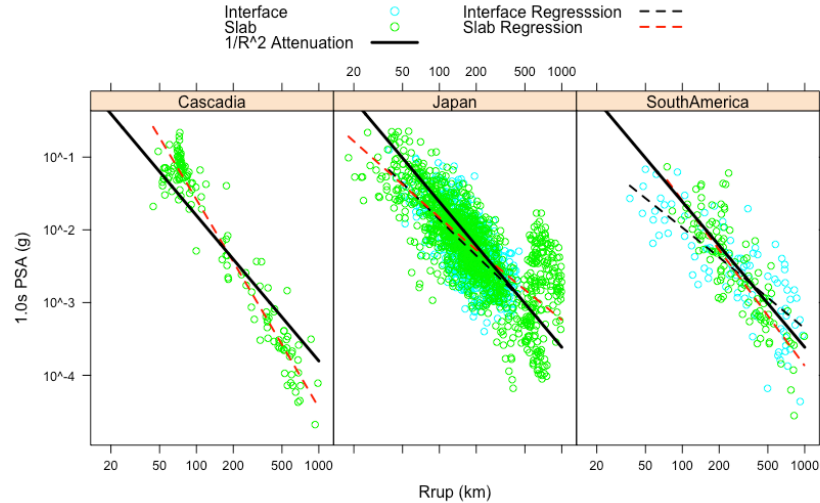


Figure 1. A comparison of 1.0s oscillator period PSA for  $6 \leq M < 7$  interface and inslab events in Japan, Cascadia, and South America. Regression fit is least squares on the binned data, using 2<sup>nd</sup> order polynomial, shown for illustration of apparent trends only.

## Model Development

### Preliminary Analysis

Because of the apparent differences in amplitude decay, we treat recordings from interface and inslab earthquakes via separate regressions throughout the modeling process. The reference velocity-corrected records are used to compute event terms ( $\eta_i$ ), which are then subtracted from the intensity measures to evaluate path effects.

In order to study data trends, the data was grouped into bins 1.0  $M$  unit in width, and the path model was fit using a nonlinear least-squares regression to data in each bin.

### Functional Form

The function for distance attenuation is given as:

$$F_p = F_z + F_{AN} \quad (1)$$

where  $F_z$  is the geometric spreading, taken as a modified version of the geometric spreading term from [6]:

$$F_Z = \begin{cases} c_0 + (c_1 + c_2 M) \ln R & \text{for } R < R_t \\ c_0 + (c_1 - c_3) \ln(R_t) + (c_3 + c_2 M) \ln(R) & \text{for } R \geq R_t \end{cases} \quad (2)$$

with:

$$R = \sqrt{R_{rup}^2 + h^2} \quad (3)$$

where  $h$  is the finite fault-rupture factor that allows for near-fault saturation of ground motion when a point-source function is used in describing attenuation away from a finite rupture. The anelastic attenuation ( $F_{AN}$ ) is represented by:

$$F_{AN} = a_1 R_1 + a_2 R_2 + a_3 R_3 \quad (4)$$

where  $R_1$ ,  $R_2$ , and  $R_3$  represent the portion of the rupture distance in kilometers in each forearc and back-arc region. The forearc distance is parameterized by  $R_1$  and the back-arc distance is parameterized by  $R_3$ . Japan has two distinct forearc regions, so for Japan only  $R_2$  is used to parameterize the distance in the second forearc region.

We anticipate setting parameter  $h$  in part from the results of simulations, and based on broad empirical and seismological considerations, because the available data is not sufficient to constrain close-distance saturation of ground motion. Parameter  $h$  has strong trade-offs with  $c_0$  and  $c_1$ . Other parameters will then be constrained by mixed effects analysis.

## Next Steps

Source terms considered include magnitude and hypocentral depth. The source model will ultimately be developed in a coupled regression with the path model, but preliminarily, we will study trends with source parameters by representing each event as a data point at a reference distance, which can then be plotted against independent variables. Site response will be analyzed considering constraints on the path and source models.

## Model Limitations

We expect our model to have limits on input parameter range, including PSA oscillator period limits of 0.1 and 10s, maximum  $R_{RUP}$  of 1000 km, maximum hypocentral depth of 200 km for in-slab events, and minimum  $\mathbf{M} = 5$ .

Additionally, we expect to have limits on regionalization and to specify subduction zones for which the global model is the most appropriate.

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