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Selection of Ground Motion Prediction Models for Subduction Zones in Costa Rica

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ABSTRACT

The selection of the Ground Motion Prediction Models (GMPM) is a key task for any seismic hazard analysis. The Interface and Intraslab subduction zones of Costa Rica are considered in this research. For the first time, a database with more than 1700 strong ground motion records, exclusively from Costa Rica, is used to check the model-data fitting. A set of GMPM is proposed for each tectonic region, also weights for the logic tree analysis are proposed. The selection process and the assignation of weights use the distribution and trends of the residuals, the likelihood, and the log-likelihood approach.

Introduction

The 2022 Costa Rican Probabilistic Seismic Hazard Analysis (PSHA) has been made as part of a UCREA transdisciplinary project at the University of Costa Rica. Two subduction seismic regions were considered: Interface (upper subduction), and Intraslab (deeper subduction). In addition, Active Shallow Crustal zones are defined, nevertheless, they are out of the scope of this paper. A set of suitable Ground Motion Prediction Models (GMPM) were preselected using the exclusion criteria of Cotton et al. [1]. A recently published strong ground motion records database [2] with records exclusively from Costa Rica, was used to examine the model-data fitting using the OpenQuake engine [3]. Five response spectra periods have been used to evaluate the behavior of the candidate models, resulting in a period-dependent selection. Previous studies for Costa Rica did not use different periods in the selection analysis, and the number of strong ground records was considerably lower than those used in this research. Finally, a proposal weight for the logic tree is made.

Strong ground motion database

The Earthquake Engineering Lab of the University of Costa Rica has a strong ground motion database that has been recently updated and published [2]. This database has more than 2400 records with a horizontal PGA equal to or greater than 2 cm/s^2. All the available records have a base correction and a bandpass filter; further details can be found in the referenced paper. A total of 1202 records from 62 earthquakes correspond to Interface seismic regions and 491 records from 26 earthquakes to Intraslab seismic regions were used. Seismic

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zonation has been defined by Alvarado et al. [4]. The distribution of magnitude (Mw) versus hypocentral distance is shown in Figure 1.

The assignation of events to a specific seismic region was made according to the earthquakes catalog of the National Seismological Network of the University of Costa Rica. This catalog has been used to define the recurrence models [5] of each seismic zone.

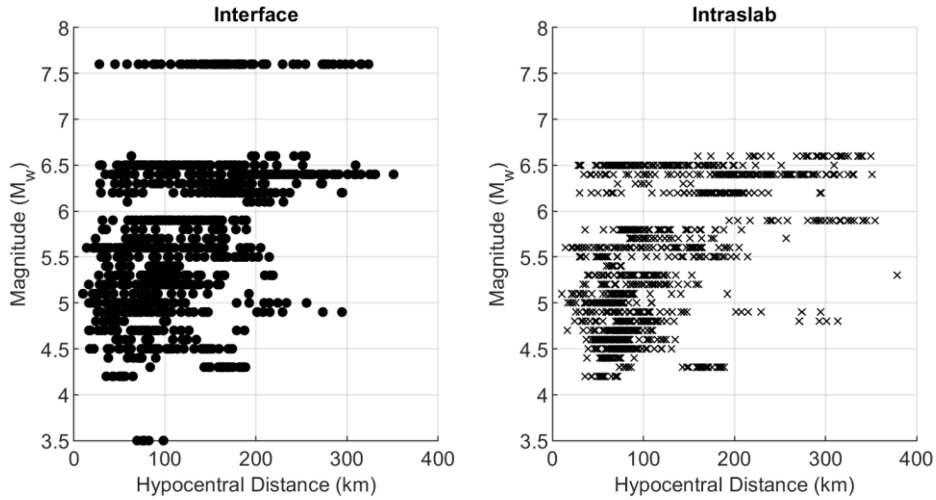

Figure 1. Magnitude (Mw) - Hypocentral distance distribution of strong ground motions record available from the Costa Rican Strong Ground Motion Database [2] to Interface and Intraslab seismic regions.

Preselected GMPM

A review of the available GMPM was made by applying the exclusion criteria of Cotton et al. [1] to the list published by Douglas [6]. The resulting models must be implemented in the Openquake engine to be considered in the analysis. The two seismic zones are considered independent, and a set of models has been selected for each one. Table 1 summarizes the main characteristics of each model.

Table 1. Preselected GMPM for subduction zones evaluated for the PSHA.

GMPM	Database	Dependent variable component	Source type	Distance (km)	Mw
Youngs et al. (1997) [7] (YO97SI) (YO97SS)	Worldwide	Geometric Mean	Interface (SI), Intraslab (SS)	10-500	5.0-8.2
Atkinson & Boore (2003) [8] (AB03SI) (AB03SS)	Worldwide	Both Horizontal (random)	Interface (SI), Intraslab (SS)	10-400	5.0-8.3
Climent et al. (1994) [9] (CL97)	Central Am., México	Largest horizontal	Interface	5-400	4.0-8.0
García et al. (2005) [10] (GA05SS)	México	Quadratic mean	Intraslab (SS)	4-400	5.2-7.4
Kanno et al. (2006) [11] (KA06S) (KA06D)	Japan	Peak square root of the sum of squares of horizontals	Interface (Shallow, S), Intraslab (Deep, D)	20-400	5.5-8.0
Zhao et al. (2006) [12] (ZH06SI) (ZH06SS)	Japan	Geometric mean	Interface (SI), Intraslab (SS)	10-300	5.0-8.2
Abrahamson et al. (2016) [13] (AB16SI) (AB16SS)	Worldwide	Average horizontal	Interface (SI), Intraslab (SS)	10-300	5.0-8.4
Lin & Lee (2008) [14] (LL08SI) (LL08SS)	Worldwide	Average horizontal	Interface (SI), Intraslab (SS)	15-630	5.3-8.1

Montalva et al. (2017) [15] (MO17SI) (MO17SS)	Chile	Average horizontal	Interface (SI), Intraslab (SS)	10-300	5.0-8.0
McVerry et al. (2006) [16] (MV06SI)	New Zealand	Largest horizontal	Interface (SI)	6-400	5.08-7.23

GMPM Selection procedure

Using the strong motion toolkit prepared by GEM [17], two general methods for model-data comparison have been used: (1) the ranking approach of Scherbaum et al. [18] using the median value of the likelihood distribution, the median, mean, and the standard deviation of the residuals and (2) the log-likelihood (LLH) approach of Scherbaum et al. [19]. The ranking obtained from (1) was used to determine the GMPM with the best fit at five different periods [PGA, Sa(0.2), Sa(0.5) Sa(1.0), and Sa(3.0)]. The LLH results were used as a tiebreaker if more than one model has the same rank and to define the proposed weights for the logic tree analysis.

Recommended GMPM for subduction zones in Costa Rica

Table 2 presents the recommended GMPM for the Interface and the Intraslab seismic regions, the results from the ranking approach following the recommendations made by Scherbaum et al. [18], and the proposed weight for the logic tree analysis. As can be seen, the behavior, for the different analyzed periods, is variable. Therefore, different weights are assigned, to achieve a reduction in the error when the PSHA is made.

Table 2. GMPM ranking according to Scherbaum et al. [18] and the proposed weight for the logic tree (LT Weight) analysis at five different periods.

Seismic Zone	GMPM	PGA		Sa(0.2)		Sa(0.5)		Sa(1.0)		Sa(3.0)	
		Rank	LT Weight	Rank	LT Weight	Rank	LT Weight	Rank	LT Weight	Rank	LT Weight
Interface	KA06S	A	0.50	B	0.35	B	0.30	A	0.60	A	0.60
	ZH06SI	A	0.50	A	0.55	B	0.30	C	0.15	B	0.30
	MO17SI	B	0.00	B	0.10	A	0.40	C	0.25	C	0.10
Intraslab	AB15SS	B	0.40	A	0.40	B	0.30	D	0.10	C	0.20
	MO17SS	D	0.00	C	0.00	B	0.30	B	0.60	B	0.60
	KA06D	C	0.20	B	0.20	C	0.10	D	0.10	D	0.00
	GA05SS	B	0.40	D	0.00	D	0.00	D	0.10	D	0.10
	LL08SS	C	0.00	A	0.40	B	0.30	D	0.10	D	0.10

Conclusions

A period-dependent selection of GMPM testing a set of suitable models, using a strong motion database with more than 1700 records, has been presented. For the Interface zones, three models were selected: KA06S, ZH06SI, and MO17SI and for the Intraslab zone, five models were selected: AB15SS, MO17SS, KA06D, GA05SS, and LL08SS. The logic tree weights for each model are proposed considering the ranking results from the Scherbaum et al. [18] approach and combining these results with the LLH weights obtained according to Scherbaum et al. [19]. The selected model and the LT weights are used in the 2022 Costa Rican PSHA.

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