The 2010 RESIS-II Seismic Hazard Model for Central America

As part of the RESIS-II cooperation project a PSHA model has been developed by a seismic-hazard team from Costa Rica, Guatemala, Honduras, Nicaragua, el Salvador, Panama, Norway and Spain (Benito et al., 2010, 2012). In this context a parametric earthquake catalog for the region was compiled and homogenized to moment magnitude, Mw. The seismotectonic models proposed in the previous phase (RESIS-I) were revised and two seismogenic zonations proposed (see details below). After a comparison with local strong motion data (statistical analysis of residuals) a set of GMPEs associated with the tectonic regimes present in the region (active shallow crust, volcanic, subduction interface, and subduction intraslab) were defined.

The original seismic hazard calculation was made using CRISIS2007 code in a grid of 0.1 x 0.1 degrees (aprox 10 km), for return periods of 200, 1000, and 2500 years. As a result, maps in terms of peak ground acceleration (PGA) and spectral accelerations SA (T) for periods of 0.1, 0.2, 0.5, 1, and 2s were obtained, as well as uniform hazard spectra (UHS) for six major cities of the region.

Basic Datasets

The parametric earthquake catalogue

Based on the catalogue proposed by Rojas et al. (1993), and with the contribution of data and experts from each country, a regional parametric catalog covering the last 500 years was created. The revision and depuration process was made using local experts following an “expert criteria scheme”. The magnitude was homogenized to Mw, using local conversion relations (see Benito et al., 2010) and the completeness analysis was made following the Stepp (1973) method. In Benito et al. (2012) a reference is made to the declustering analysis, but a detailed information about how it was made is not included.

The Seismic Source Model

Following the major tectonic structures in the region:

- The subduction zone in the plate boundary Cocos –Caribbean,
- The volcanic chain (the faults related to),
- The Polochic – Motagua transform fault in the North America – Caribbean plate boundary,
- The Panamá fracture zone in the Cocos–Nazca boundary and
- The north Panamá deformed belt.

A regional seismogenic zonation with three tectonic regimes (active shallow crustal, subduction interface, and subduction intraslab) was defined. All the source zones were defined as area sources. The crustal zones ($h \leq 25$ km) have been modeled with a 2D geometry, while a 3D geometry was considered for interface ($25 \text{ km} < h \leq 60$ km) and intraslab source zones ($h > 60$ km), with exception of the interface zone related to the north Panamá belt (flat zone at 50km of depth). A detailed description of the source zones is included in Benito et al. (2010).

The PSHA model is implemented using basically the information published in Benito et al. (2012). The source model is implemented in a unique source model file in NRML format representing the different typology and tectonic region type defined in the original model. In the active shallow crust the source zones are modelled as NRML areaSource, while in the subduction region the source zones are modelled as NRML complexFaultSource representing both, interface and intraslab sources.

The map below depicts the annual occurrence rate per source (between minimum and maximum magnitudes) for the different source models included in the hazard model. Click the *show map layers* icon to view different source models and base layer maps.

Total occurrence rate
(number of events / year)

- < 1e-6
- 1e-6 - 1e-5
- 1e-5 - 1e-4
- 1e-4 - 1e-3
- 1e-3 - 1e-2
- 1e-2 - 1e-1
- 1e-1 - 1
- 1 - 10
- > 10

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The Ground Motion Model

After a preliminary selection of GMPEs developed from tectonic environments similar to those of Central America, an analysis of residuals following the criteria proposed by Scherbaum et al. (2004) and using local strong motion data were made. The models that better fit the local data were used in the hazard calculation as a logic tree with four major branches:

GMPEs (Active Shallow Crust)
CLI94: Climent et. al. 1994
ZHA06: Zhao et. al. 2006

GMPEs (Subduction Interface)
YOU97: Youngs et. al. 1997

GMPEs (Subduction Intraslab)
YOU97: Youngs et. al. 1997

ZHA06: Zhao et. al. 2006

Scheme of the GMPE logic tree

Branch	Combination	Weight
1.	CLI94 (Active Shallow Crust) + YOU97 (Sub. Interface) + YOU97 (Sub. Intraslab)	0.25
2.	CLI94 (Active Shallow Crust) + YOU97 (Sub. Interface) + ZHA06 (Sub. Intraslab)	0.25
3.	ZHA06 (Active Shallow Crust) + YOU97 (Sub. Interface) + YOU97 (Sub. Intraslab)	0.25
4.	ZHA06 (Active Shallow Crust) + YOU97 (Sub. Interface) + ZHA06 (Sub. Intraslab)	0.25

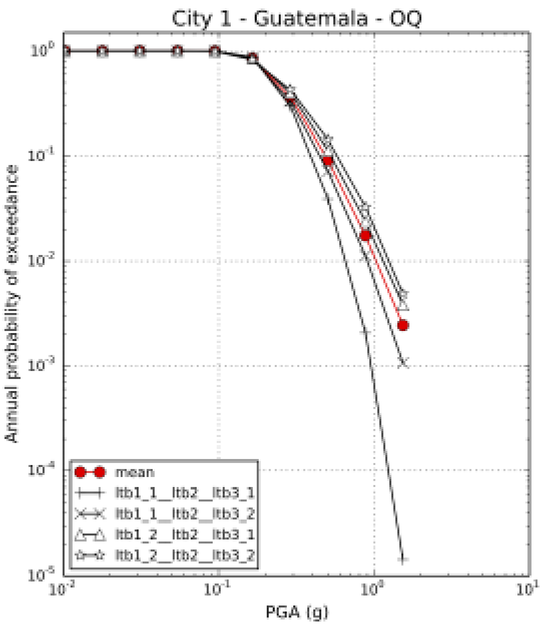
Reference site condition

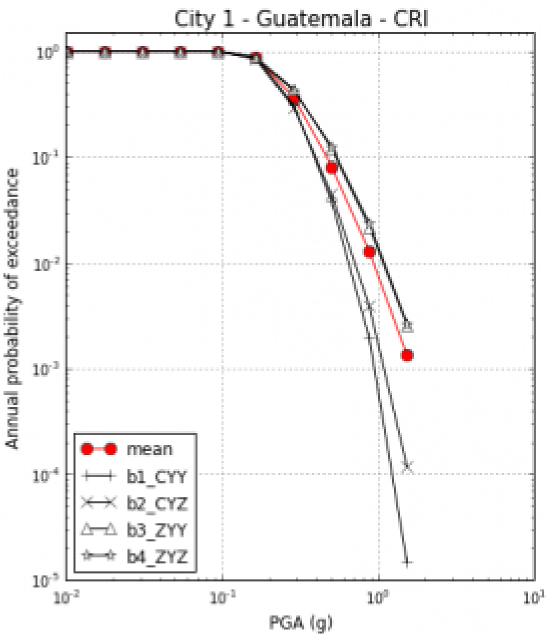
The site condition is defined using the Vs30 value in the GMPEs having this parameter as predictor variable (YOU97 and ZHA06), the remaining GMPE (CLI94) is used with coefficients already calibrated for rock conditions.

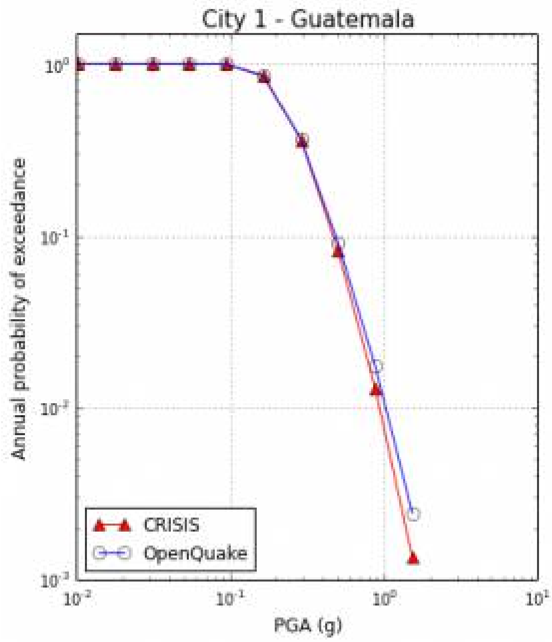
Hazard Results

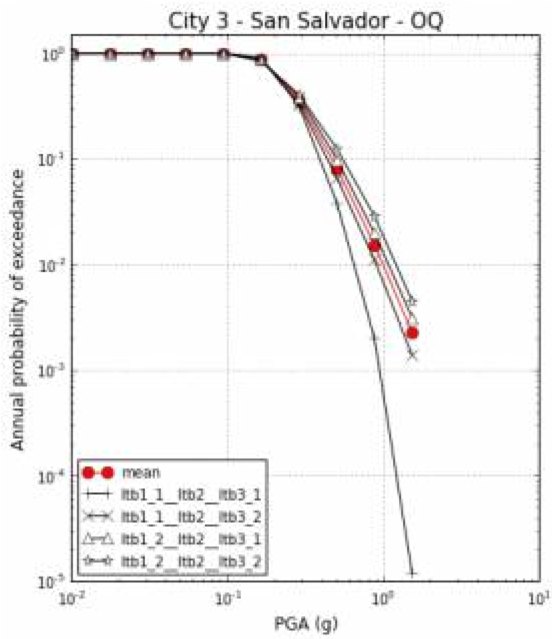
Hazard curves

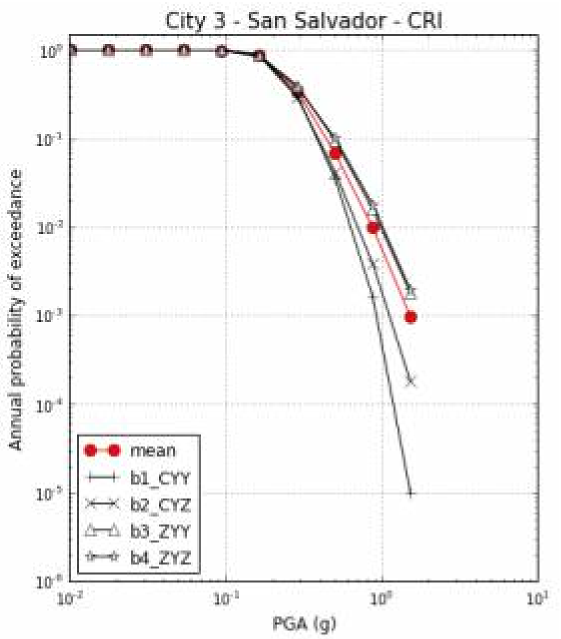
The calculation is made using the combination proposed in Benito et al.(2010) and hazard curves and maps are obtained. The figures below represent hazard curves for peak ground acceleration, for 10% probabilities of exceedance in 50 years, using the OpenQuake-engine and CRISIS for the major cities in the region. The black lines represent the results obtained in a single branch, while the red and blue ones are the mean curves from the OpenQuake-engine and CRISIS respectively. The agreement between the original results and the implemented ones is more than acceptable as seen in the figures.

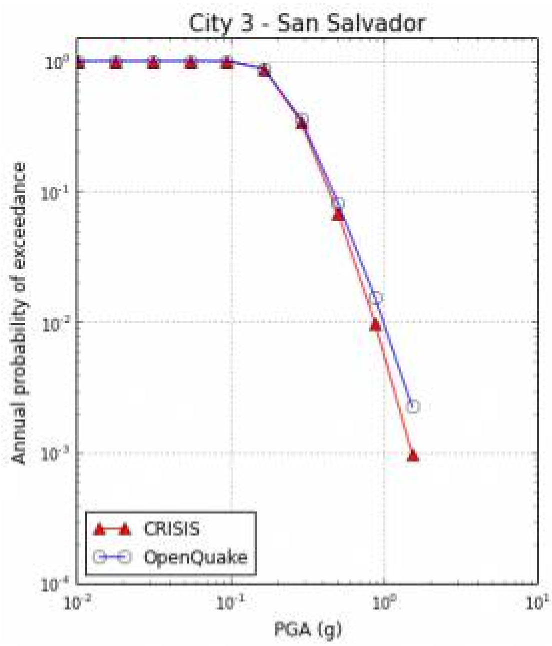


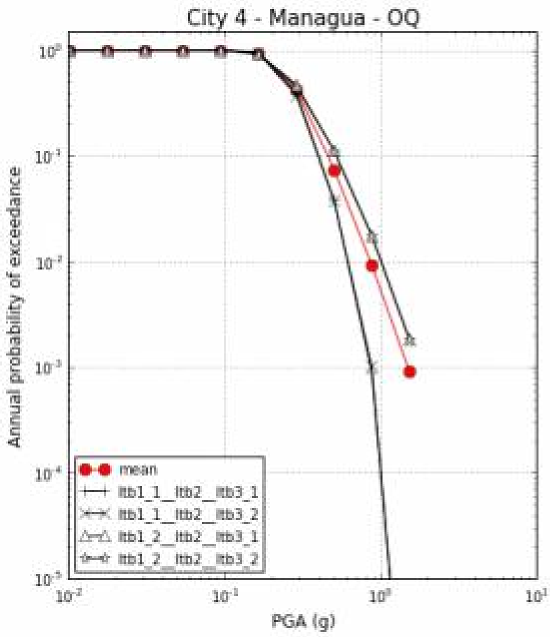


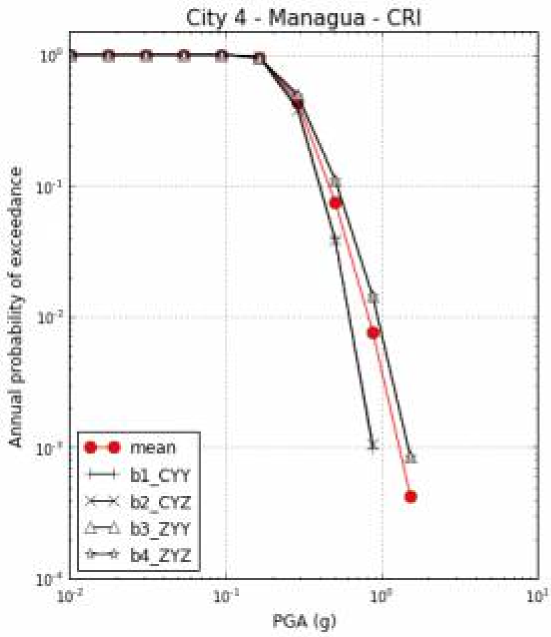

City 1 - Guatemala
Annual probability of exceedance
PGA (g)
CRISIS
OpenQuake

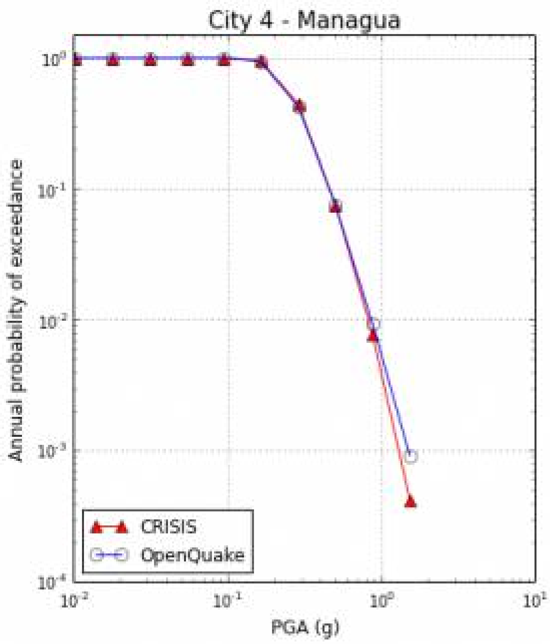

City 3 - San Salvador - OQ
Annual probability of exceedance
PGA (g)
mean
ltb1_1__ltb2__ltb3_1
ltb1_1__ltb2__ltb3_2
ltb1_2__ltb2__ltb3_1
ltb1_2__ltb2__ltb3_2

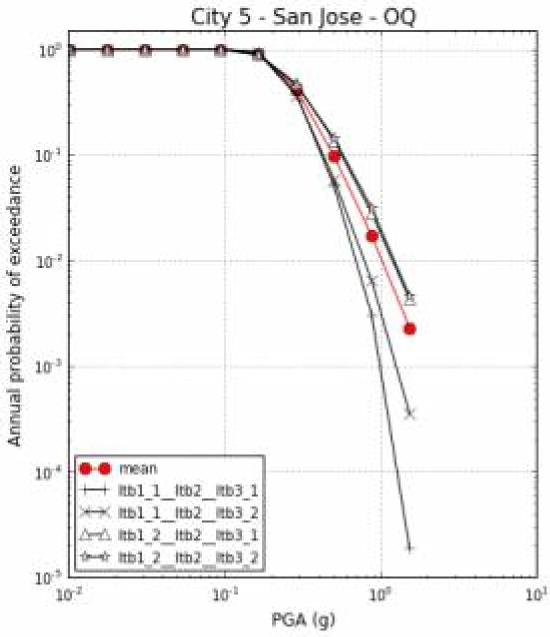

City 3 - San Salvador - CRI
Annual probability of exceedance
PGA (g)
mean
b1_CYY
b2_CYZ
b3_ZYY
b4_ZYZ

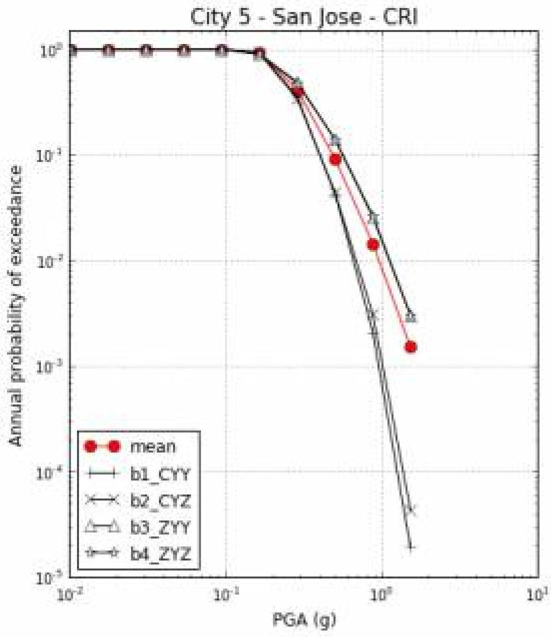

City 3 - San Salvador
Annual probability of exceedance
PGA (g)
CRISIS
OpenQuake

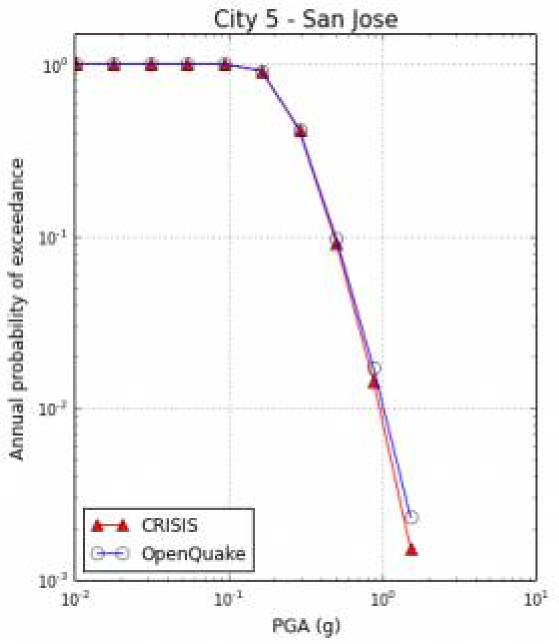

City 4 - Managua - OQ
Annual probability of exceedance
PGA (g)
mean
ltb1_1__ltb2__ltb3_1
ltb1_1__ltb2__ltb3_2
ltb1_2__ltb2__ltb3_1
ltb1_2__ltb2__ltb3_2


City 4 - Managua - CRI
Annual probability of exceedance
PGA (g)
mean
b1_CYY
b2_CYZ
b3_ZYY
b4_ZYZ


City 4 - Managua
Annual probability of exceedance
PGA (g)
CRISIS
OpenQuake

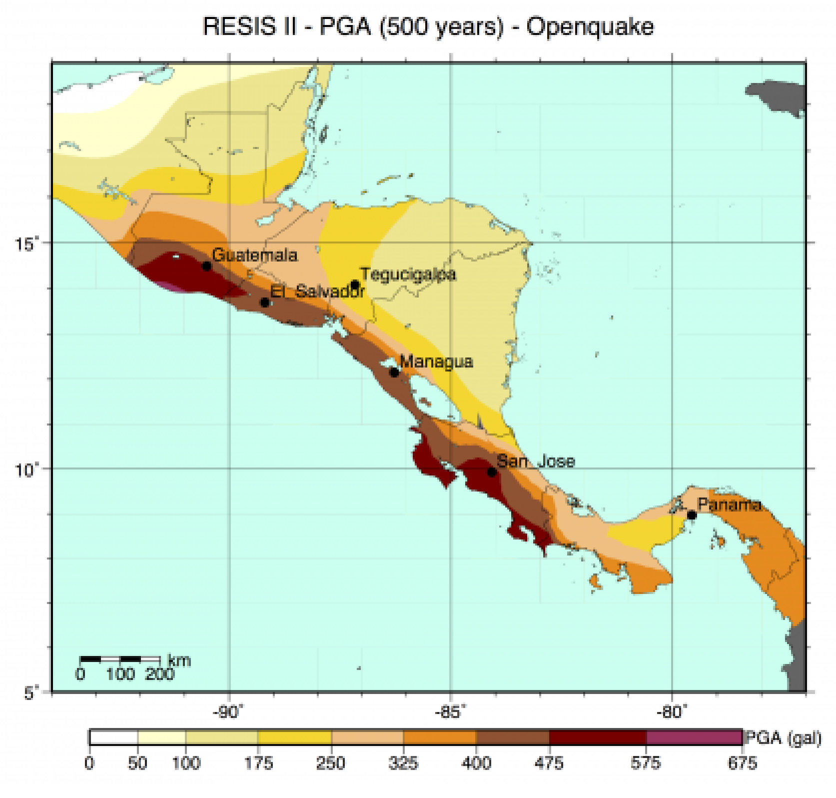

City 5 - San Jose - OQ
Annual probability of exceedance
PGA (g)
mean
ltb1_1__ltb2__ltb3_1
ltb1_1__ltb2__ltb3_2
ltb1_2__ltb2__ltb3_1
ltb1_2__ltb2__ltb3_2

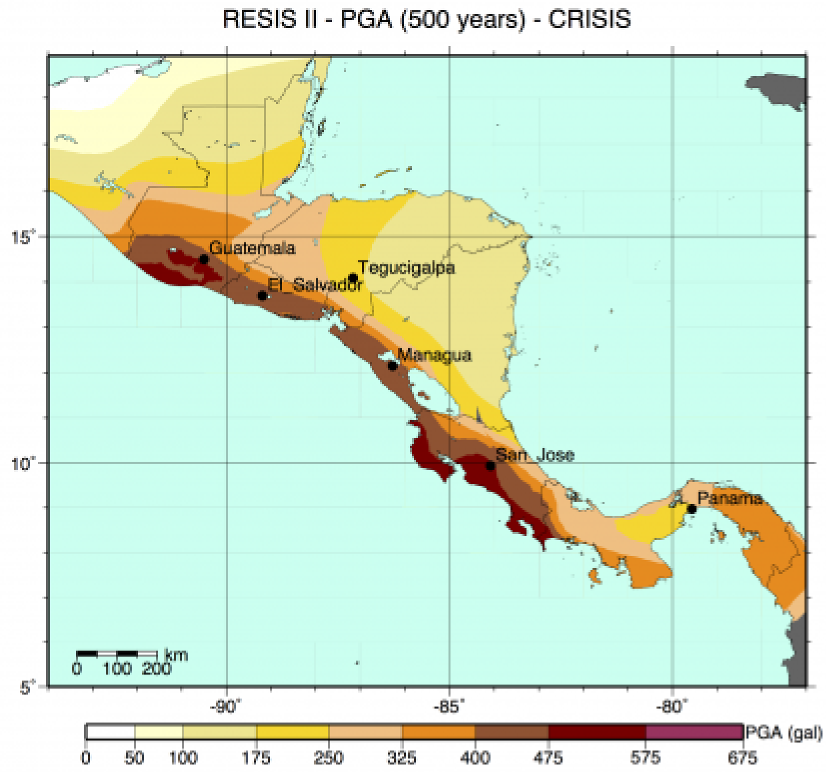

City 5 - San Jose - CRI
Annual probability of exceedance
PGA (g)
mean
b1_CYY
b2_CYZ
b3_ZYY
b4_ZYZ

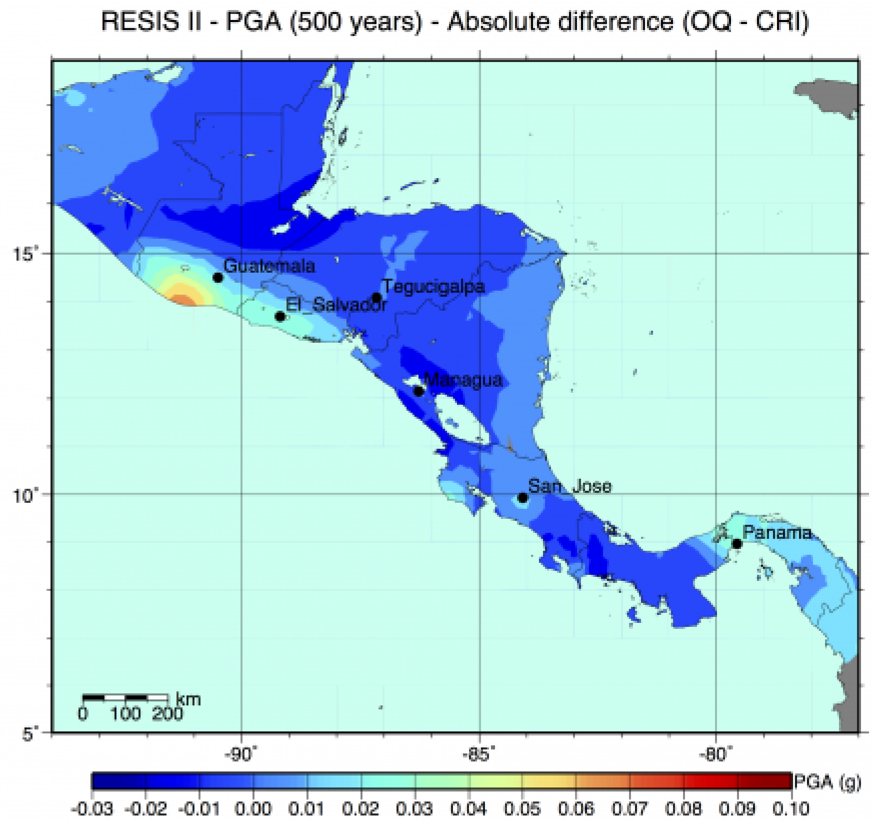


Hazard maps

The following are mean hazard maps, for 9.52% probability of exceedance in 50 years, computed with the OpenQuake-engine and CRISIS. The maps confirm a good agreement between the original and implemented models. However, a map showing the absolute difference gives a more detailed and quantitative picture of the differences. The largest ones are located along the Guatemala and El Salvador coast and are associated with the subduction interface sources and the different approaches used to model the earthquake ruptures in the OpenQuake-engine and CRISIS. It is worth noticing that differences in the implementation of Zhao et al. (2006) in CRISIS and the OpenQuake-engine for low/median magnitude values were found. Further analysis is required to better constrain what are the sources of the discrepancies.







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Model summary table

This table summarises the main characteristics of the original implementation of this model

1	**Datasets availability**	
1.1	Earthquake catalogue	Partially Available. he catalogue used is based on the ones proposed by Rojas et al. (1993) with recents contributions of data from each Central America country. The major earthquakes were published in Benito et al. (2012)
1.2	Geological database	Not Available
1.3	Strong-motion database	Not Available
1.4	Site characterization database	Not Available
Notes		
2	**Methodology for model development**	
2.1	Scientific participation (SSHAC levels) and review process	

2.2	Documentation describing model preparation	Partially Available. A general description is provided in Benito et al. (2010, 2012)
2.3	Codes used for model preparation	Not available
Notes		
3	**PSHA input model**	
3.1	**Seismic Source Model**	
3.1.1	Area sources	Considered
3.1.2	Grid sources	Not considered
3.1.3	Crustal faults	Not considered
3.1.4	Subduction faults	The subduction sources (interface and intra-slab) are modelled as area sources with a 3D-geometry
3.1.5	Non-parametric ruptures	Not considered
3.1.6	Magnitude-area scaling relationships	- Wells and Coppersmith (1994) and Brune (1970)
3.2	**Ground Motion Model**	
3.2.0	Tectonic regionalisation	Not available
3.2.1	Models for active shallow seismicity	YES
3.2.2	Models for subduction interface	YES
3.2.3	Models for subduction intraslab	YES
3.2.4	Models for stable continental regions	NO
3.2.5	Models for deep non-subduction sources	NO
3.2.6	Models for volcanic areas	NO
3.3	**Site Response Model**	
3.3.1	Based on GMPEs	YES
3.3.2	Based on site-response analysis	
3.4	**Epistemic uncertainties**	
3.4.1	Seismic Source Model	Not Included
3.4.2	Ground Motion Model	Included using a logic tree (see the ground motion model section)
3.4.3	Site Response Model	Not included
Notes		
4	**Hazard Input Description**	
4.1	Hazard input document	Not available
4.2	Input files	Not available
Notes	The GEM Foundation is grateful to the authors for making this model publicly	
5	**Calculation**	
5.1	Software	Available upon request (CRISISv.7)
5.2	**Results**	
5.2.1	Hazard curves	Not directly available
5.2.2	Hazard maps	Not directly available
5.2.3	Uniform hazard spectra	Not directly available
5.2.4	Disaggregation	Not directly available
5.2.5	Stochastic event sets	Not considered
5.2.6	Ground motion fields	Not considered
Notes		

Download The OpenQuake-engine Input Model

The OpenQuake-engine input model (NRML format) can be downloaded at the link provided below - Please read the license and disclaimer attached to the model.

N.B. This is a model adapted by GEM Hazard Team to the OpenQuake-engine from the original model developed by the Resis II team. This explains minor differences you might encounter between the results presented in the OpenQuake platform and those disseminated by the original Organisation.

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