Local vs. Regional Spectral Ground-Motion Predictive Equation for Algeria

N. Laouami & A. Slimani
Earthquake Engineering Research center, Algiers, Algeria, nlaouami@cgs-dz.org

SUMMARY

This paper deals with the development of the Algerian attenuation law based on local and regional database. Since the installation of the Algerian accelerographs network (335 stations), several earthquakes were recorded thus forming a very useful database including more than 1000 records (3<Ms<6.9 and 7< D_{hyp} <160 Km). One of the most important applications was to derive an attenuation relationship for Algeria.
The considered spectral attenuation model accounts for geometrical spreading, anelastic attenuation, and geological site conditions. The regression method, introduced by joyner and Boore (1981), is a two-step inversion [Fukushima and Tanaka, 1990; Fukushima and Tanaka, 1992]. The attenuation model describes the evolution of spectral acceleration according to magnitude, hypocentrale distance, and category of the site.
Spectral attenuation laws were derived from 1317 horizontal components homogeneously processed including Algerian strong motion records (48%), European records (42%) and American records (12%). Two models are studied, the first one considers Algerian data only, called local model, and the second one consider the whole data called regional model.
The obtained results show that the PGA standard deviation decreases from 0.331 (local data) to 0.314 (regional data), and the local model overestimates the predicted acceleration for larger magnitude. The residual values between observed and predicted spectral accelerations are studied and do not exhibit any bias. The proposed regional model is in good agreement with classical published GMPE's.

Keywords: Algeria, Attenuation, strong motion, PSA, Regional

1. INTRODUCTION

Algeria is located on the northern edge of the African plate, which is converging with the European plate since the Mesozoic, with a shortening rate of about 4-8 mm/yr (Anderson et al. 1988; Philip et al. 1987; Argus et al. 1989) (Figure 1.1). Northern Algeria is a highly seismic area, as evidenced by the historical (1365 to 1992) seismicity (Bouhadad and laouami 2002; CRAAG 1994; Benouar 1994) (Figure 1.2). During the last two decades, northern Algeria experienced several destructive moderate-to-strong earthquakes. Since the 1980 El Asnam earthquake (Ms 7.3), which claimed over 2700 lives and destroyed about 60 000 housings, many moderate, but destructive, earthquakes occurred, such as the Constantine October 27, 1985 (Ms 5.7), Chenoua October 29, 1989 (Ms 6.0), Mascara August 18, 1994 (Ms 5.6), Algiers September 4, 1996 (Ms 5.6), Ain Temouchent December 22, 1999 (Ms 5.6), Beni Ourtilane November 10, 2000 (Ms 5.5) earthquakes and the 2003 (Ms 6.8), Boumerdes May 21 which caused considerable damages and claimed over 2300 lives.
In order to perform probabilistic seismic hazard analysis (PSHA) it is necessary to have attenuation equations which relate, in probabilistic terms, magnitude and source-to-site distance with the intensity measure of interest, usually peak ground or spectral accelerations.
The lack, until recently, of strong motion data in Algeria, and the pressing need for studies of seismic hazard in different potentially seismic regions, motivated the use of American and European attenuation laws (Sadigh et al., 1993; Ambraseys and Bommer, 1991) as considered most appropriate to the Algerian context.
In this study, it has been intended to derive the attenuation relationships for PGA and PSA parameters using the earthquake records database which includes more than 1,000 records obtained since 1980.

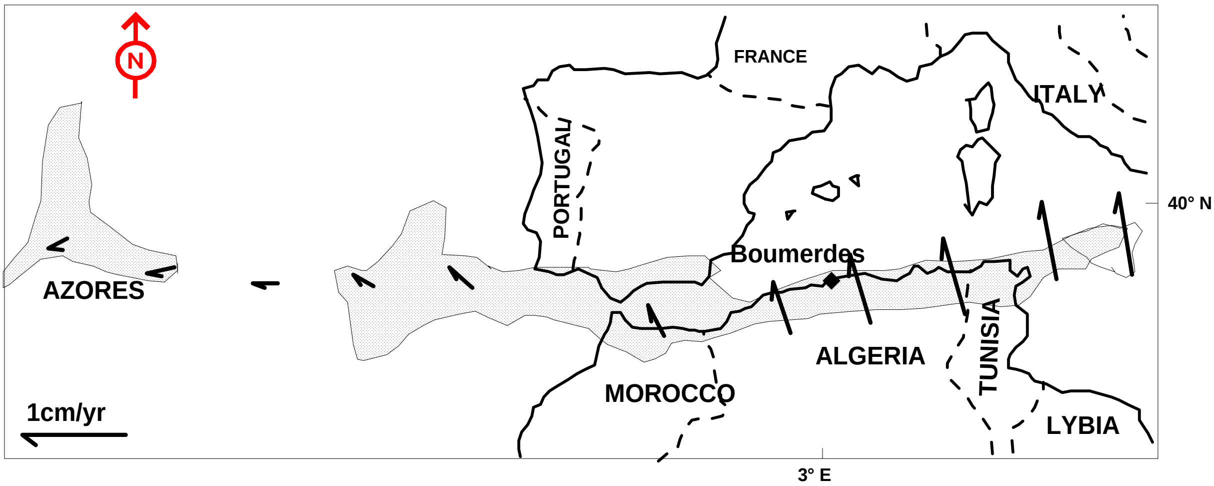

Figure 1.1: Map describing the convergence between the African and Eurasian plates (redrawn from Anderson et al. 1988). The dotted zone represents the seismicity area. The arrows indicate the shortening orientation, their length being proportional to the shortening rate. The city of boumerdes, close to the epicenter of the May 21, 2003 earthquake, is represented by a filled diamond.

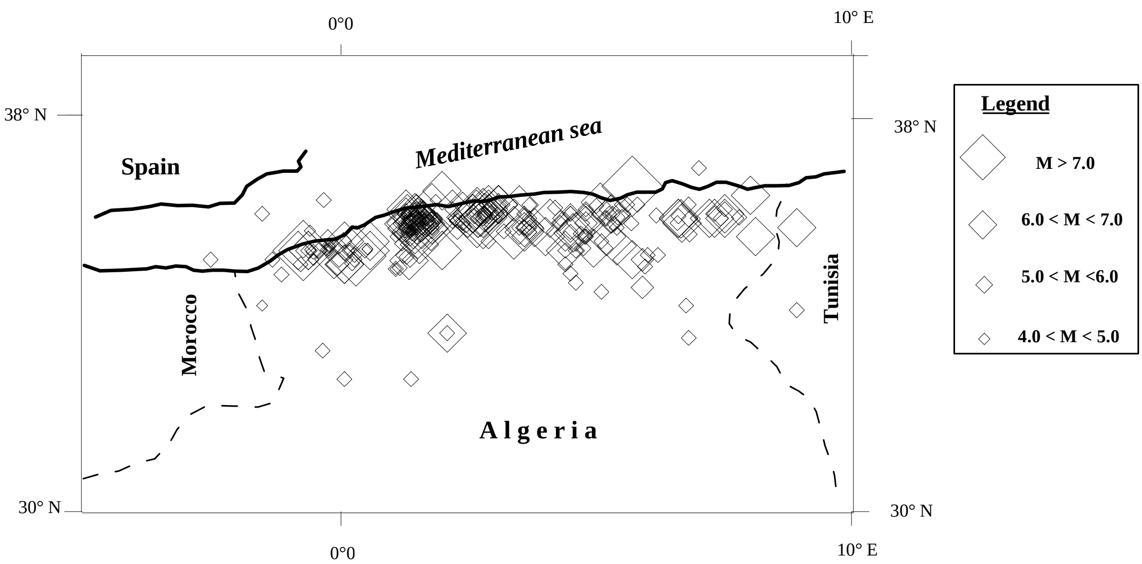

Figure 1.2: Seismicity map of Algeria for the period 1365-1992, after the catalogues of CRAAG (1994) and Benouar (1994) (Magnitudes Ms).

2. THE ALGERIAN ACCELEROGRAPH NETWORK

The lack of strong ground motion data was significantly experienced when elaborating the first Algerian aseismic building code in 1976. It was therefore decided to implement a countrywide accelerometer network. The installation of 335 3-component accelerographs started in 1980, 218 of which are already installed in the free field, and 30 in structures (buildings, dams …etc.) (Figure 2.1). The network was acquired in three stages: (i) following the 1980 El Asnam earthquake, 90 analog SMA-1 accelerographs were installed mainly in the free field, (ii) in 1990, 80 SMA-1 analog and 40 SSA-1 digital accelerographs were acquired in order to densify the existing network, with more emphasis on structures (buildings, dams), and (iii) 125 Etna digital accelerographs, acquired in 2002-2003.

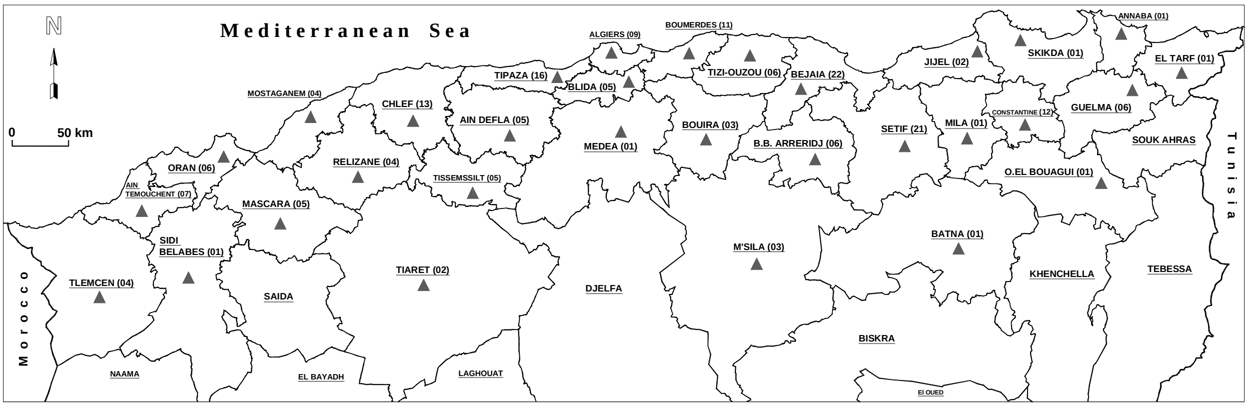

Figure 2.1: The national accelerograph network, with the regional administrative limits. The numbers in parentheses next to the filled triangles stand for the number of stations installed in the region.

3. STRONG MOTION DATABASE AND DATA PROCESSING

The strong motion database is a fundamental step for any application in the fields of earthquake engineering. Each record is characterized by several parameters such as: magnitude, distance, main or aftershock, soil type…etc.

The strong motion database contains 82 seismic events (main shock and aftershocks) since the El Asnam earthquake 10.10.1980 (M = 7.3) up to the Oran earthquake 06.6.2008 (M = 4.5).

The distribution in magnitude (from 3 up to 6.8) requires the choice of a coherent source-to-site distance. The distance used in the attenuation laws corresponds to the hypocentral distance. This choice allows accounting for both point sources and extended ruptures. Concerning the definition of the magnitude, we chose the surface wave magnitude as evaluated by USGS. Following these definitions the final dataset used to derive the attenuation laws covers a 3 to 6.8 surface wave magnitude range and a 5 to 150 km hypocentral distance domain.

Data has been processed with the Kinemetrics SWS [8] and SMA [9] softwares. Analog records were digitized using a 600 dpi scanner [10] and processed with the Kinemetrics scanview software [11]. The sampling frequency for both digital and digitized analog data has been set to 200 sps. The Trifunac method (Trifunac et al. 1973) used for data processing is based on three steps: (i) instrument correction, (ii) baseline correction of the acceleration data, and (iii) high-pass filtering of velocity and displacement, using an Ormsby filter. For instrument correction the low-pass cut-off frequency of the Ormsby filter was set to 25 Hz for the SMA-1, SSA-1, and ETNA, with a 3 Hz roll-off width. The corner frequency for both long-period baseline correction filtering and high-pass filtering of velocity and displacement, depends mainly on the spectral signal-to-noise ratio of each component, and has been estimated in the 0.12-0.2 Hz range with a roll-off width of 0.06 Hz and in the 0.2-0.3 Hz range with a roll-off width of 0.1 Hz for digital and analog data respectively.

Finally, a set of 633 data is considered for the horizontal motion (the two horizontal components assumed independent). Figure 3.1 shows the distribution of the horizontal motion database. From the distribution curve (figure 4), it appears that the Algerian database (asterisk) is very useful for the magnitude range [M_s = 3 to 6] and for distance range [D_h = 7 to 100 km], because beyond these limits, the data are insufficient and dispersed. In order to complete our data, European data (circles) (Ambraseys et al. 2000) and few American records (plus), collected from the United States Geological Survey (USGS) and the California Division of Mines and Geology (CDMG) strong motion databases, are added to the Algerian database. Finally, a set of 1317 data is considered for the horizontal motion (the two horizontal components assumed independent), with 48% of Algerian, 40% of European and 12% of American records. The influence of the added data is tested by comparing the local vs regional attenuation models.

Site condition characterisation of European data is based on Vs when it is available: otherwise, the classification is done using the available geological and geophysical information (Berge Thierry et al, 2003). For Algerian data, Vs is not available. Based on geological data and on earthquake and noise horizontal to vertical spectral ratios, most accelerometric stations in Algeria are supposed installed on firm to rock soils. Therefore, only the attenuation model for the firm to rock soil is developed in this study. A better knowledge of site, using real geotechnical and geophysical characteristics would allow to better constraining the attenuation laws.

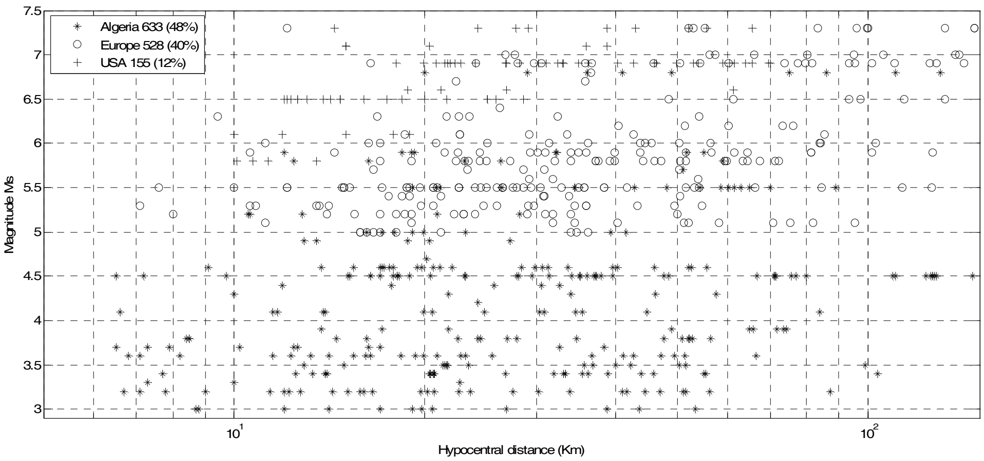

Figure 3.1 : Magnitude and distance distribution of the acceleration data.

4. LOCAL AND REGIONAL ATTENUATION LAW

4.1. Model

The attenuation model chosen to predict the seismic motion in terms of response spectrum accounts for geometrical spreading, anelastic attenuation and geological site condition. This model needs three parameters: magnitude, distance and site condition. The regression follows the two-step method [Fukushima and Tanaka, 1990; Fukushima and Tanaka, 1992], introduced by Joyner and Boore [1981], which considers independently the magnitude and the distance. The attenuatien law describes the evolution of the spectral acceleration (PSA(f)) with respect to the Ms magnitude, the hypocentral distance and the soil category, following Eqn. 3.1,

$$\log_{10} PSA(f) = a(f)M + b(f)d - \log_{10} d + c_{1,2}(f) \qquad (3.1)$$

d being the hypocentral distance, and Ms the surface wave magnitude.
The b(f) coefficient is determined in the first step, and in the second step, a(f) and $c_{1,2}$ coefficients are computed. Coefficient c_1 is for rock sites and c_2 for alluvium sites.

4.2. Results and discussions

Figure 4.1 plots the standard errors as a function of frequency obtained for local and regional models. Standard error decreases with increasing frequency, due to the low frequency noise contained in the data, and is in general more important for the local model. For the PGA value, the computed sigma is 0.314 and 0.331 for regional and local models respectively.
Figure 4.2 plots local and regional pick spectral acceleration versus frequency for different distance. It appears that the model based on local data overestimates the predicted PSA, compared to the regional model which includes European and a few American data.
Figures 4.3 present the computed residual values, the difference between the observed and the predicted values of the spectral acceleration at 0.5 Hz, 1 Hz, 10 Hz and PGA, with respect to the hypocentral distance. In the distance range of the data distribution, residual values are nearly

symmetrical with respect to zero. On the figures the standard deviation of the attenuation law at the associated frequency is also plotted. The figures show the relative scarcity of data at low frequencies (f=0.5 Hz), but do not exhibit any systematic bias (large residual values) associated to a specific distance range. Some scattered large residual values exist, which could be related to particular site effects.
We compare the present study attenuation law with published models, which are currently used in the framework of the evaluation of seismic hazard in Algeria as Ambraseys et al. [1996], Boore et al. [1997] and Berge Thierry et al. [2003]. Figures 4.4 to 4.6 display for rock sites the comparison for M = 5, 6 and 7. Because each law has its distance definition, the conversion between distance scales developed by Sabetta et al. (2005) was used.
For Ms = 5, the developed local and regional models give lowest PGA, compared to the published models. This difference is probably due to the fact that the considered lowest magnitude is 3.0 for the present study, and 5.0 for the published models. This result shows that the minimum magnitude influences the prediction of the attenuation model particularly in low seismic activity regions.
For Ms = 6.0 and 7.0, the developed regional model clearly predicts a mean seismic motion in agreement with Boore et al. (1997) and Berge Thierry et al. (2003) laws. A slight difference with these laws is probably due to the site effect. However, the local model overestimates clearly the PGA and underlines the limits to used only local data. We remark from the plotted curves that the proposed models are characterised by a fast decrease starting at intermediate distances which can be explained by the Algerian sismotectonic context.

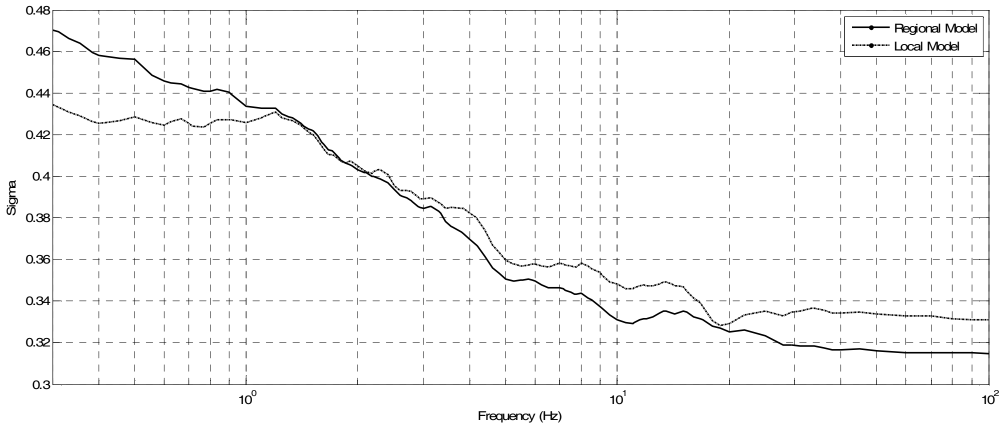

Figure 4.1: Standard errors versus frequency for regional and local models.

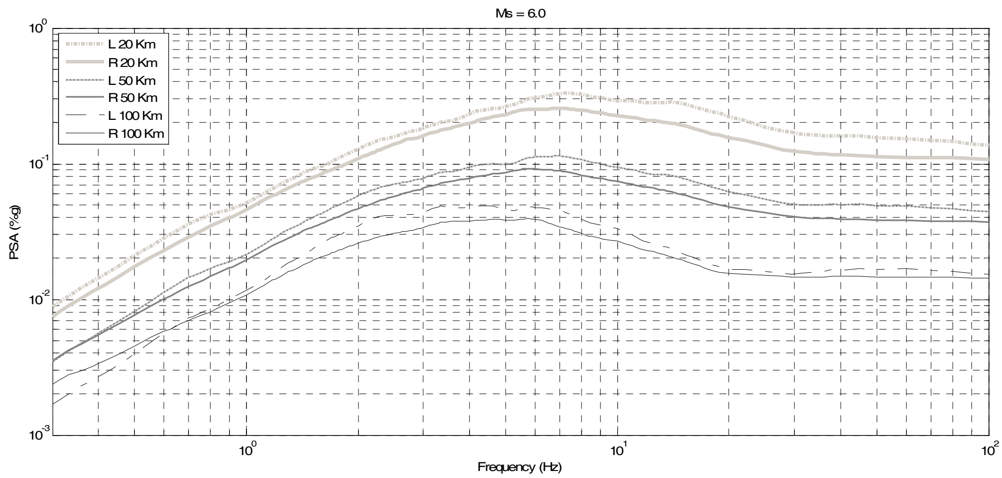

Figure 4.2: Comparison between local (L) and regional (R) developed models for different distances.

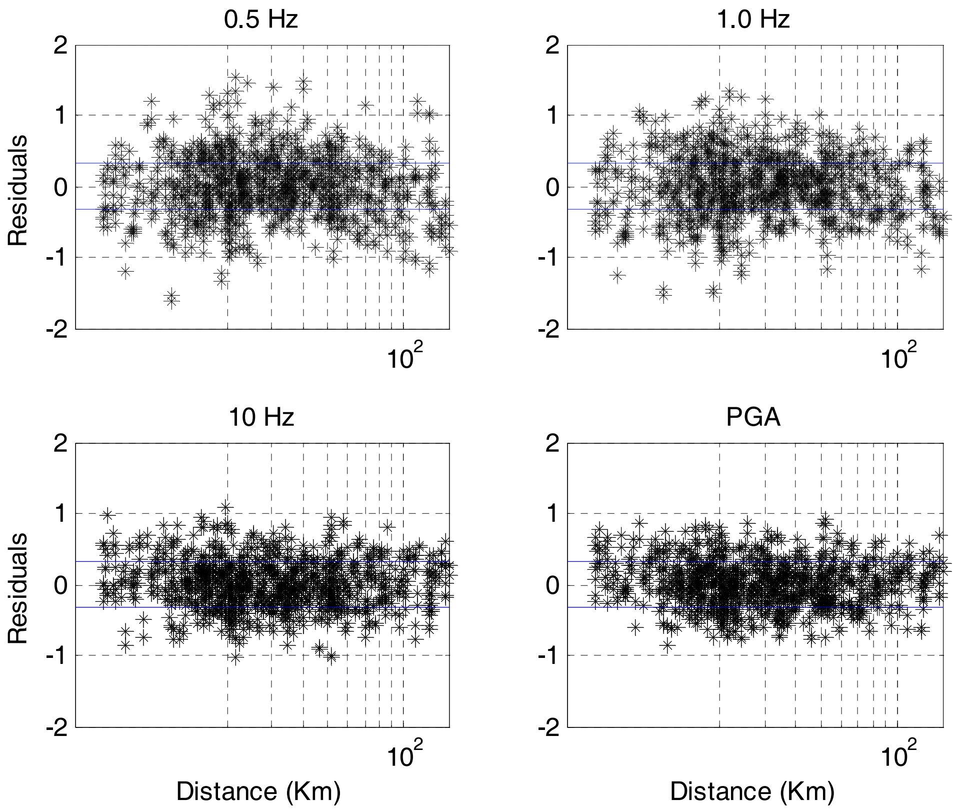

Figure 4.3 : Residuals between predisted and recorded acceleration versus distances for frequencis 0.5, 1.0, 10 Hz and PGA.

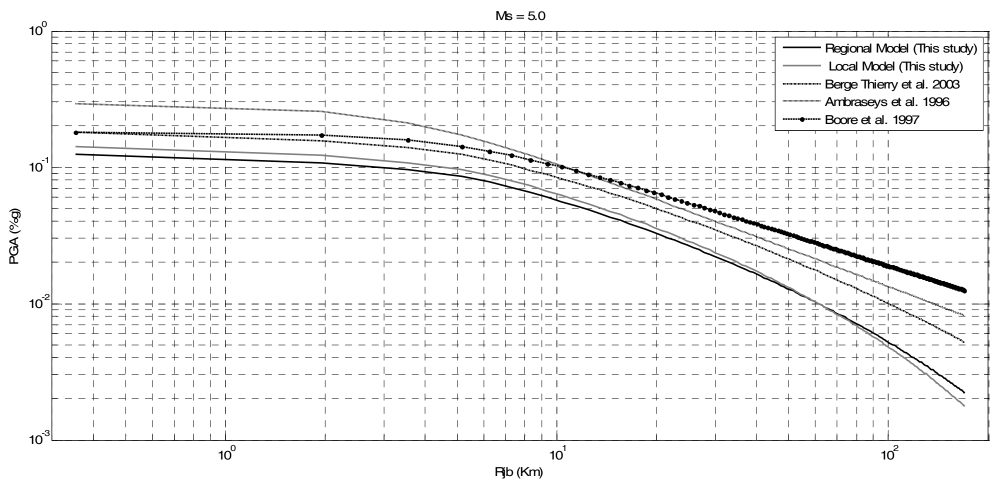

Figure 4.4: Comparison with published laws for Ms = 5.0

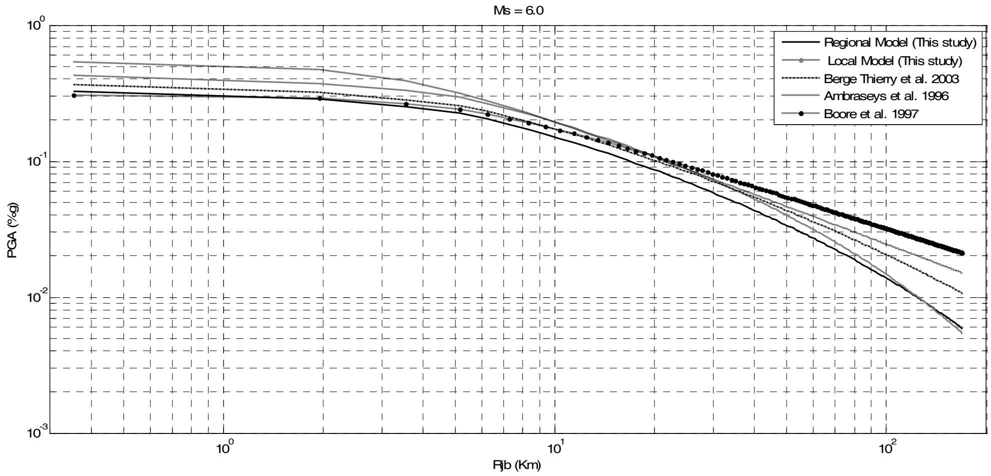

Figure 4.5: Comparison with published laws for Ms = 6.0

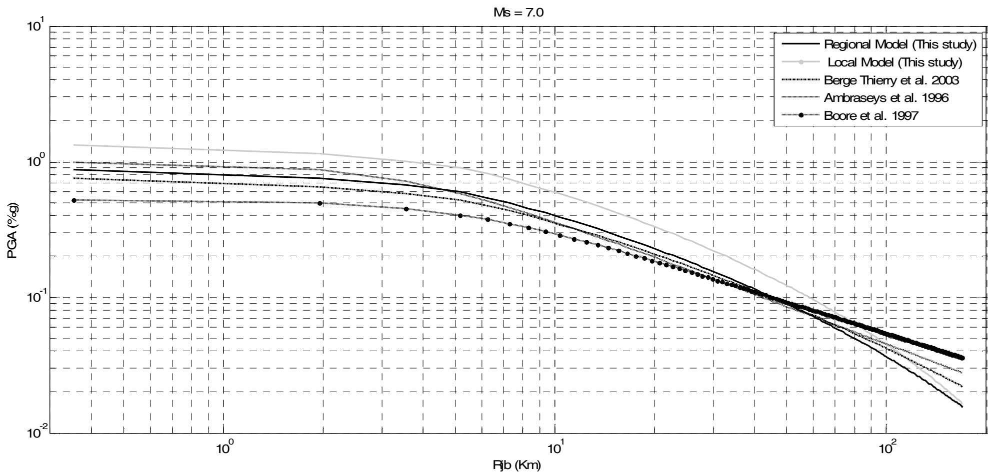

Figure 4.6: Comparison with published laws for Ms = 7.0

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