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Seismic Hazard Estimate at the Iberian Peninsula

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Abstract—Seismic hazard at the Iberian Peninsula has been evaluated by using a methodology which combines both zonified and non-zonified probabilistic methods. Seismic sources are used when considering zones where certain calculation parameters may be considered homogeneous, as in zonified methods, while, on the other hand, earthquakes are considered wherever it has taken place, as in non-zonified methods. The methodology which is applied in this paper has been originally used to calculate the seismic hazard maps in the United States. In our case, it has been necessary to adapt the method to the specific features of the seismicity in the Iberian Peninsula and its geographical surroundings, not only with respect to its distribution and characteristics, but also with respect to the properties of the seismic catalog used.

Geographically, the main feature of the result is the fact that it reflects both historical seismicity and current seismic clusters of the region. Despite the smoothing, maps show marked differences between several seismic zones; these differences becoming more noticeable as exposure time increases. Maximum seismic hazard is found to be in the southwestern region of the Peninsula, especially in the area of the Cape St. Vicent, and around Lisbon. The uncertainty of the results, without considering that due to the attenuation laws, as deduced from the other evaluation parameters, is quite stable, being more sensitive to the parameters b and $m_{\max}$ of the Gutenberg-Richter relation.

Key words: Seismic hazard, smoothed seismicity, the Iberian Peninsula.

1. Introduction

The methodology used to evaluate seismic hazard consists of a probabilistic method which combines zonified and non-zonified methods and which is based on the total probability theorem

$$P(\zeta > y) = \int_{\tilde{x}} P(\zeta > y|\tilde{x}) f_{\tilde{x}}(\tilde{x}) d\tilde{x} \quad , \tag{1}$$

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where $P(\zeta > y)$ represents the probability of an event in terms of its conditional probabilities. This indicates that the exceedance probability of a given ground motion level y can be calculated by means of a multiple integral extended to all random variables $\tilde{x}$ which affect the result, f being the density function of probability and P being the conditioned probability of exceeding y given a certain value for the intervening $\tilde{x}$ variables.

The calculation of this integral is not carried out as suggested by CORNELL (1968, 1971), but according to the methodology proposed by FRANKEL (1995) for the calculation of seismic hazard in the United States, which has been developed and modified in other works subsequently (FRANKEL *et al.*, 1996, 1997; LAPAJNE *et al.*, 1997; MUELLER *et al.*, 1998; PELÁEZ, 2000; ZABUKOVEC, 2000). These works are based on the calculation of hazard through a spatial smoothing of seismicity.

Although in the methodology by FRANKEL (1995) there is no need to use seismic sources (the b and $M_{\max}$ values are taken as homogeneous throughout most of the central and eastern United States), we use them in this work, because of the heterogeneous nature of the area under study. Seismic areas have been established where the parameters b and $m_{\max}$ of the Gutenberg-Richter truncated relation (COSENTINO *et al.*, 1977) are different. Besides, a smoothing of the parameters b and $m_{\max}$ has been carried out, as proposed by BENDER (1986).

According to FRANKEL (1995), different models are used to describe the seismicity of the area. However, unlike other works (FRANKEL, 1995; LAPAJNE *et al.*, 1997) where the weights assigned to each model remain constant, our work uses different weights for each model, depending on exposure time, so that a model covering a time interval T has a bigger contribution to the hazard calculation for a given exposure time of same order as T.

2. Data and Parameter Used

We have used the 1999 updated earthquake catalog of the Ibero-Magrhebian area (MEZCUA and MARTÍNEZ SOLARES, 1983), and the revised earthquake catalog of Portugal (LNEC, 1986). We have assigned magnitudes to historical earthquakes, through magnitude-intensity relations or through isoseismal maps (LÓPEZ CASADO *et al.*, 2000a). In order to avoid saturation of the m_b magnitude scale, we have transformed magnitudes to the M_S scale, using for that purpose the relations in LÓPEZ CASADO *et al.* (2000a). All the non-Poissonian earthquakes identified by means of a cluster analysis have been removed from the catalog as formally done by EPRI (1986), where the choice of the method parameters is carried out according to the available knowledge of the seismicity in the area. Finally, we have studied the completeness of the catalog using the methodology proposed by STEPP (1971), a key to establish the models to be used to calculate the seismic hazard.

We have taken as seismic sources the delimitation in geological domains and subdomains, with slight modifications, carried out in the Iberian Peninsula and adjacent areas by LÓPEZ CASADO *et al.* (2001). We have divided seismicity into shallow ($h \leq 30$ km) and intermediate ($30 < h \leq 60$ km), and we have neglected seismic focuses below 60 km, since they do not affect the result of the final hazard. Each of these sources (Fig. 1) has been characterized by its respective value of the parameters b, $m_{\max}$ as well as its depth (Tables 1.1 and 1.2). In order to calculate b, we have used WEICHERT'S (1980) and KIJKO'S (1984) methodologies. To calculate $m_{\max}$ we have used those proposed by PISARENKO *et al.* (1996), and KIJKO and GRAHAM (1998). The depth of each source has been obtained by averaging the depth of the epicenters in each of the sources, whenever this information is deemed reliable.

We must take into account that the attenuation relationships are one of the main causes of uncertainty in any seismic hazard evaluation (TORO *et al.*, 1997; FIELD *et al.*, 2000). Here, a regionalization of the attenuation laws has been performed to reduce the epistemic uncertainty (ANDERSON and BRUNE, 1999) using former results by LÓPEZ CASADO *et al.* (2000b). In this last work, 359 earthquake intensity maps of the Iberian Peninsula and surrounding areas led to five types of attenuation laws and to regionalize them into the study region to provide a series of zones with different attenuation laws. We believe we have reduced thus the epistemic uncertainty with laws verging on the real pattern of the attenuation laws in the area. Subsequently, other sources of uncertainties coming from the specific parameters associated with this proposed methodology will be analyzed.

Finally, we have adopted the relation between macroseismic intensity and horizontal peak ground acceleration proposed by MURPHY and O'BRIEN (1977).

3. Hazard Calculation

In order to calculate the hazard, the area under study is divided into square cells, 10 km $\times$ 10 km, as in FRANKEL (1995), and the total probability theorem is evaluated through the sum of all the cells in the area. The use of smaller cells is not justified because it increases considerably the computer time without improving the resolution of the results, while the use of greater cells would lead to further errors in the evaluation of equations (1) and (2). The methodology proposed does not rest upon the concept of source, as zonified probabilistic methods do. Instead, we have used the sources simply as a way to ascertain the values of the different calculation parameters (b and $m_{\max}$) which are needed for some specific location (calculation cell).

Equation (1) is usually expressed in terms of the exceedance rate $\lambda(y)$

$$\lambda(y) = \sum_k \sum_l \lambda(m_l, r_k) P(\zeta > y | m_l, r_k) \tag{2}$$

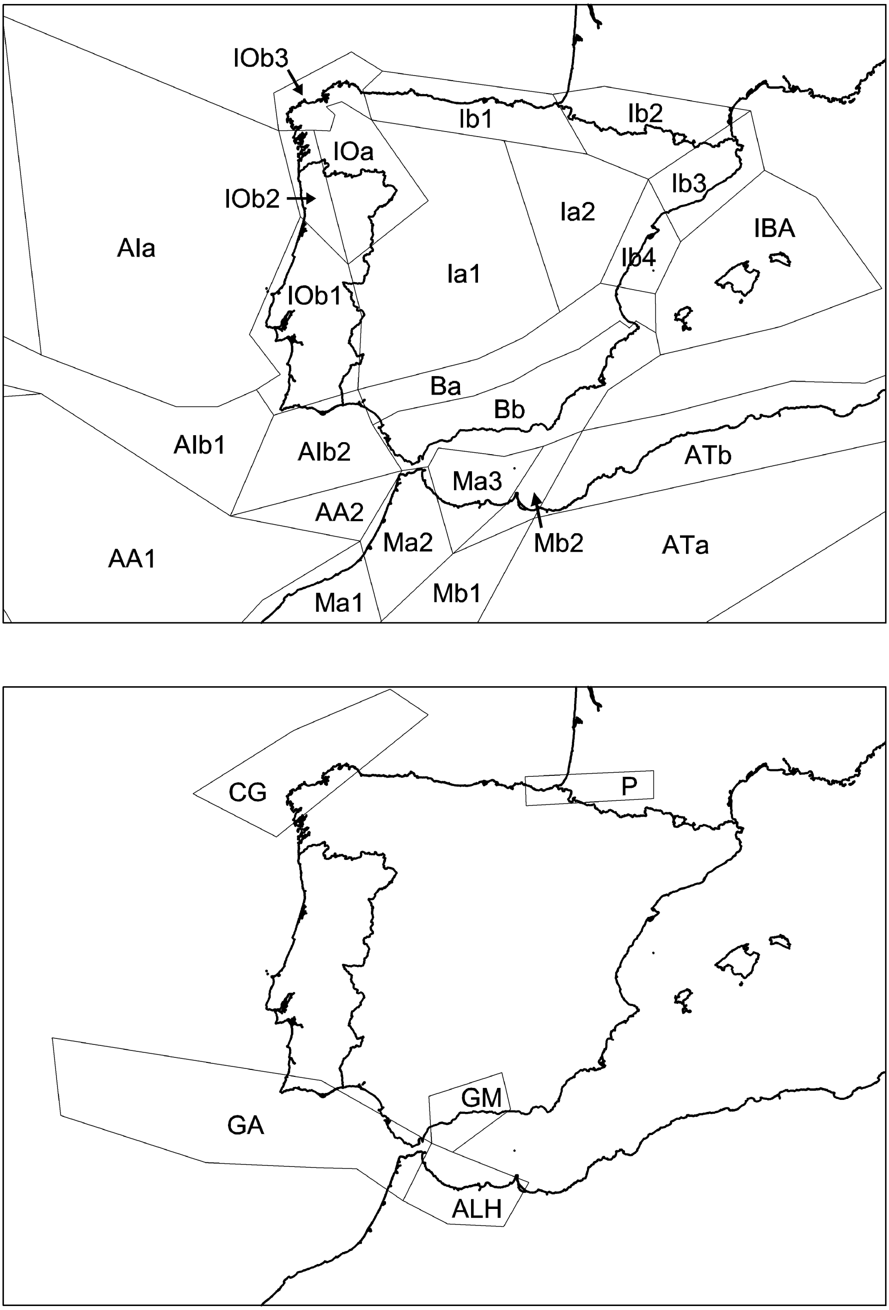

Figure 1
Seismic sources used to evaluate the seismic hazard in the Ibero-Maghrebian area. In the top panel, we show the sources that include the shallow seismicity ($h \leq 30$ km). In the bottom panel, we indicate those including intermediate seismicity ($30 < h \leq 60$ km).

Table 1.1

b, d (depth) and $M_{S\max}$ parameters, with their uncertainty, calculated for the sources that include the shallow seismicity. (*) This value is in the M_W scale

Seismic source	b, σ	d, σ (km)	$M_{S\max}$, σ			
			Model 1	Model 2	Model 3	Model 4
AA1	0.40, 0.07	7, 11	8.2, 0.57	8.2, 0.57	8.2, 0.57	8.2, 0.57
AA2	0.41, 0.13	22, 12	4.9, 0.57	4.9, 0.57	6.3, 0.75	6.3, 0.75
Ma1	0.66, 0.10	7, 10	4.5, 0.43	4.5, 0.43	4.5, 0.43	4.5, 0.43
Ma2	0.66, 0.10	10, 5	4.8, 0.59	5.3, 0.59	6.2, 0.72	6.2, 0.72
Ma3	0.66, 0.06	8, 7	6.1, 0.43	6.2, 0.52	6.2, 0.52	6.2, 0.52
Mb1	0.69, 0.08	5, 7	6.0, 0.59	6.0, 0.59	6.0, 0.59	6.0, 0.59
Mb2	0.67, 0.09	6, 2	5.3, 0.32	5.3, 0.32	5.3, 0.32	5.3, 0.32
ATa	0.46, 0.02	8, 9	5.7, 0.51	5.7, 0.51	6.3, 0.76	6.3, 0.76
ATb	0.46, 0.02	9, 8	7.4, 0.33	7.4, 0.33	7.4, 0.33	7.4, 0.33
AIa	0.61, 0.07	8, 10	5.6, 0.42	6.1, 0.58	6.2, 0.72	6.2, 0.72
AIb1	0.47, 0.03	11, 12	8.3*, 0.58	8.4*, 0.52	9.7*, 0.76	9.7*, 0.76
AIb2	0.64, 0.06	18, 8	7.1, 0.58	7.1, 0.58	7.1, 0.58	7.1, 0.58
IOa	0.73, 0.11	8, 6	5.2, 0.51	5.2, 0.51	5.2, 0.51	5.2, 0.51
IOb1	0.64, 0.05	10, 8	5.3, 0.58	5.3, 0.58	6.8, 0.76	6.8, 0.76
IOb2	0.71, 0.14	12, 4	3.4, 0.52	4.8, 0.59	4.8, 0.59	4.8, 0.59
IOb3	0.74, 0.23	10, 10	4.0, 0.59	4.4, 0.51	4.4, 0.51	4.4, 0.51
Ba	0.55, 0.05	5, 3	5.1, 0.32	5.1, 0.32	6.2, 0.72	6.2, 0.72
Bb	0.67, 0.03	6, 6	5.2, 0.51	5.2, 0.51	7.3, 0.76	7.3, 0.76
Ia1	1.04, 0.28	9, 5	3.4, 0.50	3.4, 0.50	3.6, 0.70	3.6, 0.70
Ia2	0.54, 0.12	2, 2	4.5, 0.58	5.1, 0.55	5.1, 0.55	5.1, 0.55
Ib1	0.86, 0.15	12, 6	4.3, 0.44	4.9, 0.60	4.9, 0.60	4.9, 0.60
Ib2	0.73, 0.05	5, 4	5.6, 0.59	6.0, 0.59	6.2, 0.72	6.2, 0.72
Ib3	0.62, 0.07	6, 4	5.3, 0.58	5.3, 0.58	5.3, 0.58	6.2, 0.72
Ib4	0.62, 0.07	6, 4	3.1, 0.58	3.5, 0.58	4.5, 0.76	5.3, 0.76
IBA	0.62, 0.07	15, 12	4.9, 0.58	4.9, 0.58	5.3, 0.76	6.3, 0.76

Table 1.2

b, d (depth) and $M_{S\max}$ parameters, with their uncertainty, calculated for the sources that include the intermediate seismicity

Seismic source	b, σ	d, σ (km)	$M_{S\max}$, σ
P	0.73, 0.05	32, 1	3.3, 0.43
CG	0.64, 0.31	36, 4	4.5, 0.43
GA	0.73, 0.11	40, 8	5.6, 0.59
GM	0.54, 0.16	55, 6	5.8, 0.58
ALH	0.59, 0.29	44, 11	4.3, 0.58

where the index k is extended to all cells (r_k is the distance between the point of calculation and each of the cells being considered) and the index l is extended to all magnitudes; in fact, the first sum is carried out only up to a certain distance $r_{\max}$ from the point of calculation (as far as to the point where the attenuation relation indicates that there is no contribution to hazard), while the second sum is considered between the values of magnitude m_o and $m_{\max}$, the latter parameter depending on the considered cell (seismic source).

In equation (2) the first term of the sum over k and l is the rate of earthquakes with magnitude m_l in a cell at a distance r_k from the point of calculation, depending only on the energetic distribution which is being considered for the seismicity in the zone. It can be written as

$$\lambda(m_l, r_k) = \frac{N_k}{T} q(m_l, \Delta m) \tag{3}$$

where N_k is the number of earthquakes that have taken place at a given cell, during a time interval T in which the catalog is believed to be complete above the minimum magnitude being considered in the calculation. The function q is the fraction of earthquakes in the interval of magnitude $m_l \pm \Delta m/2$ which can be calculated through the integral

$$q(m, \Delta m) = \int_{m-\frac{\Delta m}{2}}^{m+\frac{\Delta m}{2}} f_M(m)dm \ , \tag{4}$$

where f is the probability density function for magnitudes. In our calculation, we shall use the truncated Gutenberg-Richter relation, where f takes the value (COSENTINO *et al.*, 1977)

$$f_M(m) = \frac{b10^{-b(m-m_o)} \ln 10}{1 - 10^{-b(m_{\max}-m_0)}} \tag{5}$$

so that, after replacing (5) into (4) we derive

$$q(m, \Delta m) = \frac{10^{-b(m-m_0)}}{1 - 10^{-b(m_{\max}-m_0)}} \left[10^{b\frac{\Delta m}{2}} - 10^{-b\frac{\Delta m}{2}} \right]. \tag{6}$$

The second factor in the summatory of equation (2) is the conditioned probability that, given a magnitude m_l earthquake at a distance r_k from a certain place, the ground motion level y should be exceeded at this place. In this work this factor is calculated through the complementary accumulative function of the standardized normal distribution of

$$\frac{y - \bar{y}}{\sigma_y}, \tag{7}$$

where the variable y used is the macroseismic intensity, $\bar{y}$ is the mean value of the intensity at a distance r_k from the epicenter, given through the attenuation relation used, and σ_y is the deviation assigned to such attenuation relation.

From the exceedance rate given by equation (2) it is possible to calculate the intensity or acceleration expected, the return period and the ground-motion level which will take place at a given exposure time with a certain probability.

In this methodology, unlike that of zonified methods, we do not assume a constant rate of earthquake generation in each source. On the contrary, we consider seismicity where it has taken place, and we count the number of earthquakes recorded in each of the cells directly (N_k).

For the smoothing of the value N_k we use a Gaussian filter (FRANKEL, 1995). With this smoothing we expect to include the uncertainty in the earthquake location in the result of the hazard. In this work, not only N_k is smoothed, but also the parameters b and $m_{\max}$, as BENDER (1986) has proposed for smoothing the hazard contrasts observable in the boundary of seismic sources. In the Gaussian filter, the value of a given parameter in a given cell is obtained by averaging the values in the surrounding cells, the value in each of them contributing with equal weight to

$$\exp\left(-\left(\Delta_{ij}/c\right)^2\right) \tag{8}$$

where Δ_{ij} is the distance between cells i and j, and c is a parameter of the filter, called the correlation distance. The most important advantage of this filter is the fact that it keeps the total number of earthquakes constant.

4. Models

Five different models are used for the hazard calculation; each of them covering a different number of years T, and being complete above a certain minimum magnitude $M_{S\min}$ (Table 2). In order to establish them, we have considered the study of completeness conducted on the catalog (STEPP, 1971). In four models (1 to 4) shallow seismicity ($h \leq 30$ km) has been included, while in the fifth one we have included seismicity at a depth of 30 to 60 km. The earthquakes below 60 km do not contribute significantly to seismic hazard, according to their magnitudes and the attenuation laws. Hazard was calculated for each of the models considered by establishing the average hazard obtained in models 1 to 4 and by adding to this result the one

Table 2

This table shows the time interval (T) during which every model is complete above $M_{S\min}$. We also include the correlation distance (c) used to smooth the seismicity in each model

	Seismicity since	T	$M_{S\min}$	c (km)
Models 1 & 5	1960	40	2.5	5
Model 2	1920	80	3.5	10
Model 3	1700	300	4.5	15
Model 4	1300	700	5.5	20

obtained through model 5. Table 2 shows the characteristics and parameters considered in each model.

Unlike Frankel's methodology, we have not included the characteristic earthquake model to describe the most energetic seismicity ($m_b > 7.0$), since in our studied area we have insufficient tectonic information for this model to be introduced. Average recurrence times for events related to particular faults in the area are not known. Likewise, we have considered it unnecessary to use a model based on a uniform source including all observed seismicity (uniform background zone) due to the geographical and historical extension of the catalog used. Moreover, the latter model, which was introduced with the idea of allowing earthquakes to take place in areas where none has been observed in the past, implies a hazard decrease in the most active zones.

It has been necessary to complete and normalize the seismicity included in the models (Fig. 2), counting the earthquakes in each cell. The reason for this need to complete the seismicity is the fact that the minimum magnitude m_o, chosen to calculate the hazard, is the value 2.5 M_S, the threshold magnitude for models 1 and 5. This value ensures that we keep all the information on probabilities and return periods for intensity VI obtained from the evaluation of equation (1) and the use of a maximum value of 0.55 in the standard deviation of the considered attenuation laws (LÓPEZ CASADO *et al.*, 2000b). The magnitude above which models 2, 3, and 4 have been considered complete is greater than the value 2.5 mentioned above (see Table 2). To carry out this process, we added as many earthquakes as we deemed necessary, adjusting the seismicity of the influence zone to a Gutenberg-Richter relation, and distributing them in proportion to the number of earthquakes in each cell.

It has also been necessary to normalize the seismicity included in the models (FRANKEL, 1995; LAPAJNE *et al.*, 1997). Thus, in the four models including shallow seismicity, the annual rate of earthquakes in the influence zone as a whole must be the same, so that all models have the same number of earthquakes per year above any magnitude after the completeness and normalization processes. The four models are constrained to preserve the activity rate of seismicity; the only change being their spatial distribution. Model 1 has the highest annual rate above any magnitude, so that models 2, 3, and 4 have been normalized to it.

For models 1, 2, 3 and 4, we have considered the same value of parameters b and depth of the source in each of the seismic sources that have been delimited. However, in each of the models we have used different values of parameter $m_{\max}$; in general, the greater exposure time is, the greater registered maximum magnitude or intensity are.

5. Results

The results obtained (Fig. 3) are the peak horizontal acceleration maps with 39.3%, 10%, and 5% probability of exceedance in 50 years (return periods of 100,

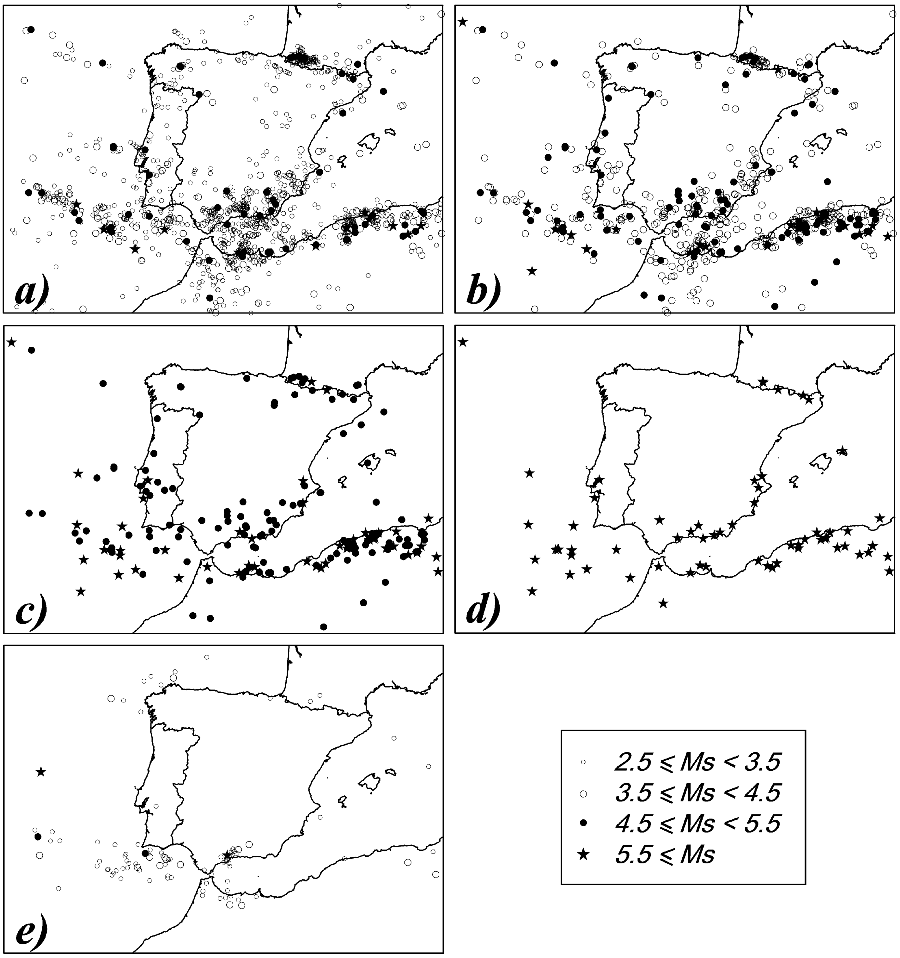

Figure 2
Seismicity included in the different models. a) Model 1: shallow seismicity from 1960 with $M_S \geq 2.5$. b) Model 2: shallow seismicity from 1920 with $M_S \geq 3.5$. c) Model 3: shallow seismicity from 1700 with $M_S \geq 4.5$. d) Model 4: shallow seismicity from 1300 with $M_S \geq 5.5$. e) Model 5: intermediate seismicity from 1960 with $M_S \geq 2.5$.

475 and 975 years, respectively). For that purpose we have subjectively weighted the hazard results calculated separately with models 1, 2, 3 and 4. Different values are proposed for the weights according to exposure time, intending in all cases that the models comprising a time interval comparable to the exposure time provide the most important contribution. Other subjective assumptions could be used: i.e., more weight for a model with more "reliable data." Once hazard has been calculated, the hazard generated by model 5 is added to it. Besides these maps, we have also

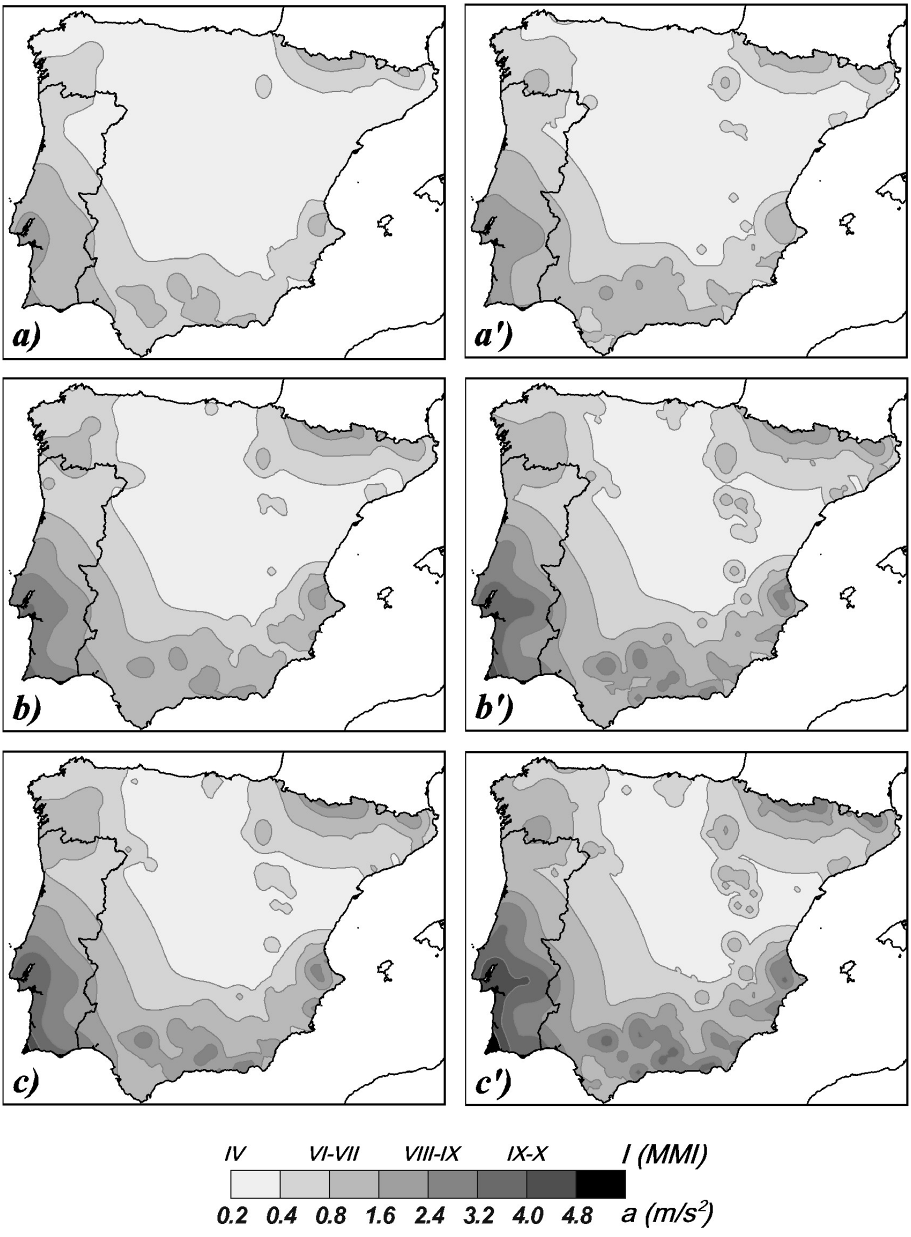

Figure 3

Different results obtained for the seismic hazard. Panels a), b) and c) show the averaged hazard, and panels a′), b′) and c′) correspond to the worst-case. a) and a′) are for peak accelerations with 39.3% probability of exceedance in 50 years (return period of 100 years). b) and b′) are for peak accelerations with 10% probability of exceedance in 50 years (return period of 475 years). c) and c′) are for peak accelerations with 5% probability of exceedance in 50 years (return period of 975 years).

calculated the so-called worst-case, where maximum seismic hazard is represented in each location given by some of the models.

According to the results obtained, the maximum peak accelaration values reached in the Iberian Peninsula are within the range of 2.0 ($I_{MM} \approx$ VIII), 4.3 (IX-X), and 5.8 m/s^2 (X), for the return periods of 100, 475 and 975 years, respectively. In the worst-case these values slightly increase, however they are extended to larger regions. Geographically, the greatest seismic hazard has been obtained for the southwest of the Peninsula, because of the earthquakes of the Azores-Gibraltar fault and of the Lisbon zone. Next in the hazard scale come the zones of the south, southeast and northeast of Spain, where the less stable geological structures of the Iberian Peninsula are located (Betic and Pyrenean zones). It has been shown that intermediate seismicity ($30 < h \leq 60$ km) substantially contributes to seismic hazard in the southernmost zone of Spain.

The differences between these maps, shown in Figure 3, are slight: they lie mainly in the fact that, as the return period increases, the size of the areas affected by a certain degree of hazard increases too. In the third result, that corresponding to the greater return period, we can better appreciate the historical seismic focuses where the most energetic earthquakes have occurred. However, the first result, the one most affected by current seismicity, also shows historical seismicity; rather than to localize hazard zones, what the model including historical seismicity really does is to constrain their maximum level and their geographical boundaries.

Figure 4 shows the seismic hazard curves evaluated at four selected sites in the Peninsula, namely Lisbon and Faro, in the west and south of Portugal respectively, and Granada and Málaga, in the south of Spain.

Due to fact that attenuation laws are the main source of uncertainties in seismic hazard results, we have used our most recent and possibly most precise attenuation

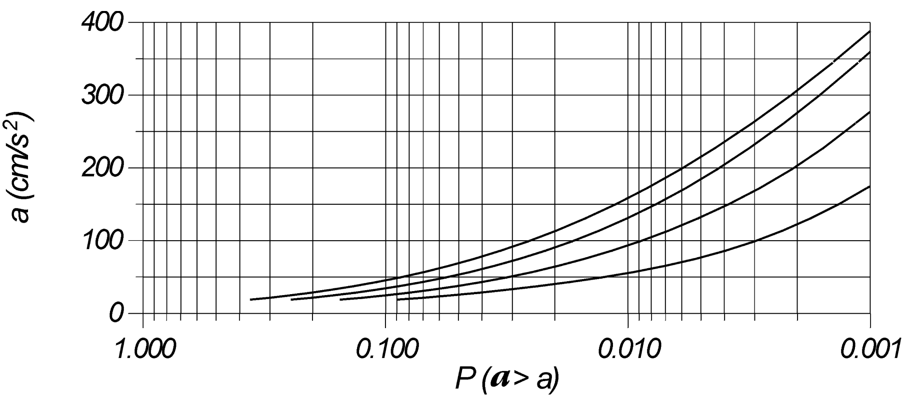

Figure 4
Seismic hazard curves for different locations. From top to bottom, they correspond to Lisbon, Faro, Granada and Málaga.

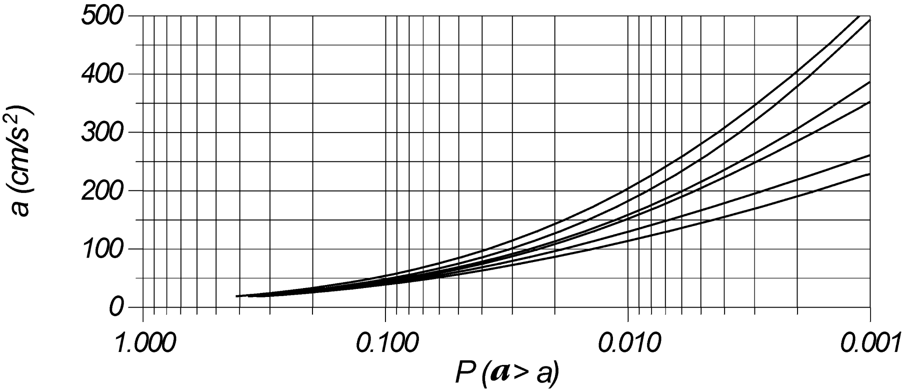

Figure 5
Seismic hazard curves for the city of Lisbon. The significance levels are 5, 15, 50 (median), 63 (expected value), 85 and 95%.

laws available for this zone (LÓPEZ CASADO *et al.*, 2000b). Thus, once performed the reduction of epistemic uncertainties from the attenuation laws, and after a previous sensitivity analysis on the influence of parameters N_k, d (depth), b and m_{max}, we have focused on the uncertainties arising only from such parameters associated with our seismic hazard methodology.

From the sensitivity analysis of the results we have concluded that the results are more sensitive to the m_{max} and b parameters. Therefore, we have used these two parameters in the uncertainty analysis. To be more precise, bearing in mind the uncertainty in our knowledge of each parameter in each seismic source, we have used simulations when trying to obtain particular results in different localizations. In order to characterize the uncertainties when expressing the results, we have used the fractile levels 0.05, 0.15, 0.50 (median), 0.63 (expected value), 0.85, and 0.95, these being the values recommended by the SSHAC (1997), since the results obtained after the simulations do not follow a normal distribution. Figure 5 presents a particular case in which the uncertainty of the result becomes relevant; the different hazard curves, drawn for the former fractile levels, obtained for the city of Lisbon. It also shows (Table 4) the uncertainty in the expected acceleration, due to parameters b and m_{max}, for the four cities whose seismic hazard curves appear in Figure 4.

6. *Conclusions*

The variant of FRANKEL'S (1995) method introduced in this work is used to evaluate seismic hazard in the Iberian Peninsula, while taking into account both the seismic characteristics and different tectonic features of the regions delimited in the Iberian Peninsula. This implies allowing for the advantages of both the zonified and

Table 3

Weights for the contribution of each model as a function of the exposure time

Probability of exceedance in 50 years	Model 1	Model 2	Model 3	Model 4
39.3%	0.25	0.25	0.25	0.25
10%	0.20	0.20	0.30	0.30
5%	0.20	0.20	0.20	0.40

Table 4

Uncertainty in the expected acceleration for the cities listed in the header. The expected acceleration (m/s^2) is shown, for the different levels of significance α, with 5% probability of exceedance in 50 years

α	Peak acceleration (m/s^2) for			
	Málaga	Granada	Faro	Lisbon
0.05	0.92	1.31	2.27	1.85
0.15	0.99	1.61	2.61	2.12
0.50	1.22	2.27	3.22	3.00
0.63	1.31	2.44	3.45	3.22
0.85	1.50	2.80	3.69	3.96
0.95	1.72	3.22	4.24	4.55

non-zonified methods in the evaluation of seismic hazard. Thus, apart from the smoothing of the tectonic differential features in the region (seismic sources), seismicity is smoothed as well. Results are consistent not only with the tectonic features of the zone, but also with the size of the earthquakes recorded in the last 700 years. As we have also used regionalized attenuation laws, we can hopefully claim that the epistemic uncertainty introduced into our calculation model has decreased. Moreover, as more and better data have been introduced than in previous works, closer approaches to the real physical pattern of the attenuation laws in the area are expected.

Geographically, the main feature of the results is the fact that they clearly are characterized by both the historical seismicity and the current seismic clusters of this region. The intermediate seismicity ($30 < h \leq 60$ km) somewhat affects the seismic hazard in the southernmost zone and in the southwest of the Iberian Peninsula, so that it is mandatory in any hazard calculation carried out for this zone. Despite the smoothing, the maps indicate clear differences among the different seismic zones; a fact which becomes more noticeable as time exposure increases.

According to the peak accelaration map with 10% probability of exceedance in 50 years, the Iberian Peninsula may be classified into three zones. The first one is a zone of high seismic hazard ($2.4 < a < 4.0$ m/s^2) in the southwest of the Iberian

Peninsula (Lisbon–Cape St. Vicent–Algarve). The second zone, which may be considered as having moderate seismic hazard ($0.8 < a < 2.4$ m/s^2), comprises the southwest, the south, the southeast, and the northeast of the Peninsula, apart from a small region in the northwest of the Peninsula. The third zone is the rest of the Iberian Peninsula, almost two thirds of it, and it shows low seismic hazard ($a < 0.8$ m/s^2).

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