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Extreme Earthquake and Earthquake Perceptibility Study in Greece and its Surrounding Area

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Abstract. The sample interval for the selection of extreme magnitudes plays an important part in the quality of Gumbel model fitting. A short sample interval can produce many observations, which is helpful in obtaining a reliably fitting model. However a short sample interval can bring many dummy “observations”, a condition which adversely biases the fitting. The short sample interval also increases the chance to introduce non- independent observations as well, which violates a basic requirement of the Gumbel model. On the other hand, a large time interval not only reduces the number of observations, but also enlarges the observation error. Thus, for Greece, the most suitable parameters of the third Gumbel extreme model are obtained by using a sample interval which produces minimum error. In consideration of the reliability of the seismic data, earthquakes with magnitude $M \geq 5.5$ in Greece and its surrounding region after 1900 are used mainly in the present paper. In order to obtain well resolved contour maps with smooth changes a $2° \times 2°$ cell with half-degree overlap strategy was used to scan the region. The most expected largest earthquake for the next fifty, one hundred and two hundred years are estimated for each cell. Likewise, the events with magnitude at a probability of 90% of non-exceedance over the next fifty, one hundred and two hundred years are estimated for each cell. In parallel to this procedure we also analyze the 67 shallow seismic zones outlined by Papazachos and his colleagues and detail individual zone results where these are obtained. The most perceptible earthquake magnitude for the range of intensities I = VI, VII and VIII are also calculated. All results show that the areas around the Hellenic Arc and the Cephalonia Transform Fault for Greece have comparatively high frequency of destructive earthquakes accompanied by a high occurrence probability of moderate earthquakes ($M \geq 5.5$).

Key words: Gumbel model, earthquake, extreme value, perceptibility, Greece.

1. Introduction

Statistical methodology plays a major role in estimating the return period, viz, the average inter-event time, the size and the location of seismic activity since no successful physical method yet proves to be effective.

Many memoryless models require a complete data set, a demand which proves to be difficult to realize in practice, especially for the data of small events before the installation of the World Wide Seismological Stations Network (WWSSN) in 1964 (Pacheco and Sykes, 1992). However, the extreme value theory described by

Gumbel (1958) has the advantage that it does not depend excessively on a complete record of earthquake occurrence, but instead on the sequence of earthquakes constructed from the largest values of magnitude over a set of predetermined intervals (i.e., the sample interval) (Burton, 1979). The extreme values are usually better known than the smaller events in a catalogue. This is a simple but important advantage. Also, selection of the extreme values will largely eliminate most significant aftershocks from the analysis and maintain emphasis on what are held to be independent events (Makropoulos and Burton, 1985). Therefore, Gumbel theory has been used in earthquake research by many seismologists (Yegulalp, 1974; Yegulalp and Kuo, 1974; Burton, 1978, 1979, 1981; Makropoulos and Burton, 1985).

Nordquist (1945) demonstrated that the 'Theory of Extreme Values' is applicable to the estimation of the probability of occurrence of maximum magnitude earthquakes. The theory of extreme values is generally formulated under the following assumptions: the prevailing conditions should be valid in the future and the observed largest values be independent of each other (Yegulalp and Kuo, 1974). Distribution of extreme values, like Poisson's law, are linked to small probabilities. Poisson's law gives the number of rare events, while the theory of extreme values considers their size.

There are three kinds of Gumbel model, labeled for convenience: Gumbel I, Gumbel II and Gumbel III. Yegulalp and Kuo (1974) and Burton (1979) claimed that the third asymptotic distribution has a clearer and better physical interpretation for a probabilistic model describing earthquake magnitude occurrence than either the first or the second distribution. The present paper uses the Gumbel III theory (i.e., the third asymptotic distribution) to study the seismicity pattern in Greece and its surrounding area. The parameters of the third asymptotic distribution of extreme values are estimated throughout the region with a scanning cell of $2° \times 2°$ degrees, within which the largest earthquakes and those with 90% probability of non-exceedance over the next fifty, one hundred and two hundred years are estimated. The magnitude of the most perceptible earthquake at different intensity levels (VI, VII and VIII) is also calculated. In order to obtain detailed information throughout the study region, a scheme with half degree overlap between cells is adopted. The method thus develops the capabilities of a zone-free analysis of seismicity; this has also been developed elsewhere in relation to a peak ground acceleration seismic hazard analysis (Burton *et al.*, 2003). In parallel to this zone-free analysis we also adopt for analysis the 67 shallow seismic zones outlined by Papazachos and Papazachou (1997) and Papaioannou and Papazachos (2000). These zones were delineated in an attempt to maintain a degree of seismotectonic homogeneity (Papazachos, 1990).

2. Data and Tectonic Setting

In consideration of the reliability and completeness of regional seismic data, the data for the present study, except where stated otherwise, are shallow earthquakes (depth $h \leq 60$ km) with magnitude $M \geq 5.5$ (M is surface wave magnitude) in Greece and its surrounding regions that have occurred since 1900. The current catalogue is mainly developed on the foundation studies of Makropoulos and Burton (1981), Engdahl *et al.* (1998) and Papazachos *et al.* (2000), and is described in full in Burton *et al.* (in press). This earthquake catalogue has already been used successfully elsewhere to develop a peak ground acceleration seismic hazard analysis for Greece (Burton *et al.*, 2003). Although the major target is to achieve a zone-free methodology for the analysis of seismicity, 67 shallow seismic zones (depth $h < 60$ km) around the Aegean Sea, as described by Papazachos and Papazachou (1997) and Papaioannou and Papazachos (2000), were also unequivocally adopted.

Greece and its surrounding area is located in the Eurasian-Melanesian zone of the continental fracture system and the Hellenic arc (Ionian islands – Crete – Rhodos), toward which the Eurasian plate and the African plate converge (Papazachos and Papazachou, 1997). Specifically, due to the southwestward motion of the southern Aegean relative to Europe, the active Hellenic subduction in the south, the westward push of Anatolia in the east and the continental collision between northwestern Greece and the Apulian platform in the west, Greece and its surrounding area experiences the highest seismicity in Europe (Figure 1).

The low angle thrust faults of shallow earthquakes, which are located along the Hellenic Trench, mark the southern boundary of the Aegean plate. A strike slip dextral fault belt dominates the northern part of the Aegean plate. The northwestern edge of the Aegean plate is delineated by the Cephalonia Transform Fault (Scordilis *et al.*, 1985). The boundary in the eastern part of the Aegean plate is dominated by a broad zone of east-west extensional normal faults (Papazachos and Papazachou, 1997).

3. Methodology

3.1. EVALUATION OF THE PARAMETERS

The third asymptotic model for the unit-interval (i.e., the basic sample-interval, here taken to be one year so that each extreme magnitude can be treated as independent) takes the form (i.e., probability function):

$$\mathrm{GIII}(m) = \exp\left[-\left(\frac{\omega - m}{\omega - \mu}\right)^{1/\lambda}\right], \tag{1}$$

where GIII(m) is the third Gumbel cumulative probability of magnitude less than or equal to m, ω the upper limit of earthquake magnitude, μ the characteristic extreme magnitude, λ the shape parameter and m the extreme magnitude value. When m tends to its upper limit ω, the function GIII(m) $\to 1$, whereas when m decreases, the function GIII(m) $\to 0$.

In order to reduce possible correlation between the extreme magnitudes and to minimize the number of dummy observations (extreme interval with null entry) in

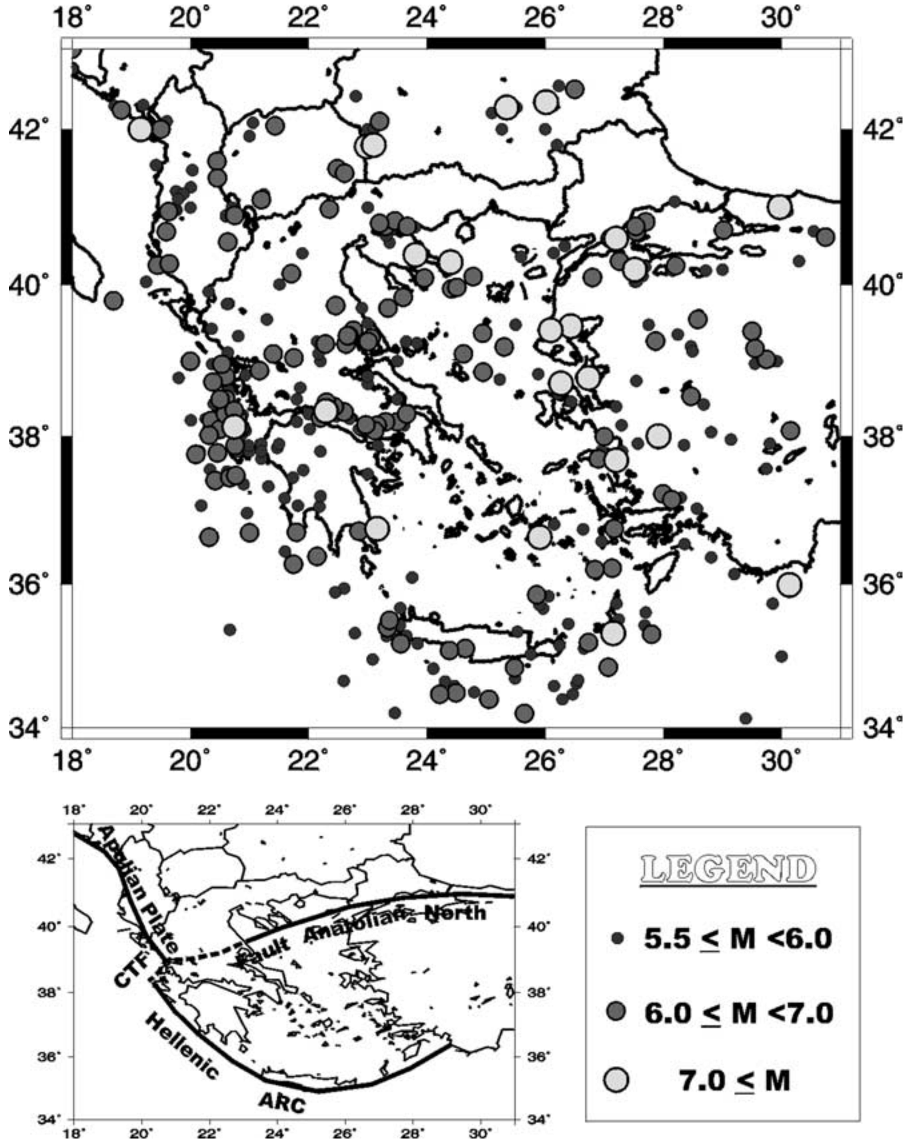


Figure 1. The earthquake distribution with magnitude $M \geq 5.5$ during 1990–1999 and the tectonic setting of the study region.

the data sequence for a lower seismicity region, a relatively large sample-interval is preferred. A larger sample-interval makes the observational data more evenly distributed and will tend to improve the model fitting. Take the following example to illustrate this (Figure 2): If the time sequence is divided into twelve intervals (i.e., twelve observations), the meaningful extreme observations above the threshold will be four out of twelve; eight out of the twelve will be dummy observations, the efficiency of observation is four to twelve. If divided into six intervals (i.e.,

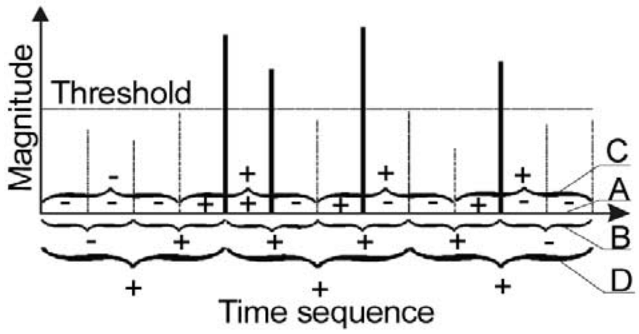


Figure 2. Formation of the extreme value with different time-intervals. The "+" sign indicates the interval with meaningful observation (above the threshold), whereas the "−" sign indicates any interval with dummy observation. (A) illustrates the case with only four meaningful observations out of twelve samples (i.e., eight dummy observations); (B) four out of six; (C) three out of four and (D) three out of three. The efficiency of the four cases increases in the order A, B, C and D.

six observations), the efficiency will be four to six. If divided into four intervals (i.e., four observations), the efficiency will further increase to three to four, and so on. The increasing "efficiency" of the observations, therefore the uniformity of the data, will tend to increase the fitting quality if the number of observations is sufficiently large.

However, it must be borne in mind that this increasing efficiency is at the cost of a sharp reduction in the number of observations, which will adversely influence the fitting quality. Additionally, due to the limited magnitude space, the larger the sample interval then the larger will be the extreme magnitude and the less will be the magnitude range of the data set. These factors will eventually bias the model fitting. Therefore there exists an optimum sample interval which leads to best model fitting (Burton, 1981). Taking T-year as a sample interval and further assuming that the annual extreme magnitudes are independent of each other, then the T-year Gumbel III probability function can be written as (Yegulalp and Kuo, 1974):

$$\mathrm{GIII}^T(m) = \prod^T \mathrm{GIII}(m) = \exp\left[-T\left(\frac{\omega - m}{\omega - \mu}\right)^{1/\lambda}\right]. \tag{2}$$

The above relation can be rewritten as:

$$m = \omega - (\omega - \mu)[-\ln \mathrm{GIII}^T(m)/T]^{\lambda}. \tag{3}$$

Gringorten (1963) has shown that the plotting position of the extreme probability follows:

$$\mathrm{GIII}^T(m_i) = (i - 0.44)/(n + 0.12) \quad i = 1, \ldots, n, \tag{4}$$

where i is the order when the extreme magnitude m_i is ranked in ascending order, n the number of the extreme events. This plotting position is thus an approximation to the extreme probability calculated directly from the ranked sequence of extremes prior to curve fitting. In order to obtain the parameters ω, μ and λ of the relation (3), nonlinear model fitting is used to minimize χ_T^2value (Burton, 1979; Press *et al.*, 1992),

$$\chi_T^2(\omega, \mu, \lambda) = \sum w_i(m_i - \tilde{m}_i)^2, \tag{5}$$

here w_i is the weight associated with the observation, m_i the magnitude and $\tilde{m}_i$ the model of relation (3). Briefly (see above references for full description), to minimize relation (5),

$$AX = B, \tag{6}$$

where

$$A = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}, \; a_{ij} = \frac{1}{2}\frac{\partial^2 \chi_T^2}{\partial x_i \partial x_j}, \quad i, j = 1, 2, 3$$

$$B = \begin{bmatrix} b_1 \\ b_2 \\ b_3 \end{bmatrix}, \quad b_i = -\frac{1}{2}\frac{\partial \chi_T^2}{\partial x_i}, \quad i = 1, 2, 3$$

$$X = \begin{bmatrix} \omega \\ \mu \\ \lambda \end{bmatrix}.$$

Note that the second derivative of relation (5) is ignored because of its negligible influence when compared to the terms involving the first derivative. Inclusion of the second-derivative term can actually be destabilizing if the model fits poorly or is contaminated by outlier points that are unlikely to be offset by compensating points of opposite sign (Press *et al.*, 1992).

To efficiently solve the matrix (6), the Levenberg-Marquardt method (also called Marquardt method) (Marquardt, 1963) is used for the required nonlinear least-squares fitting. This method readjusts the diagonal elements of matrix **A** of the relation (6), i.e.:

$$\begin{aligned} a'_{jj} &= a_{jj}(1 + \xi) \\ a'_{jk} &= a_{jk}, \quad (j \neq k), \end{aligned}$$

where ξ is an adjustable number. When ξ is very large, the matrix is forced into being diagonally dominant so that the solution of (6) can be written as:

$$x_j = \frac{b_j}{\xi a_{jj}}.$$

On the other hand, as ξ approaches negligibly small (i.e., $\xi \to 0$), the solution is the same as that of relation (6). At first, ξ is set to a small but non-negligible value and a trial solution set $(\tilde{\omega}, \tilde{\mu}, \tilde{\lambda})$ of (6) adopted in order to estimate the starting value $\chi_T^2(\tilde{\omega}, \tilde{\mu}, \tilde{\lambda})$. This procedure is repeated with a new ξ value so that the new value of χ_T^2 decreases until the decrement is not significant. As discussed above in relation to data efficiency, the above procedure is repeated for different extreme time intervals to find

$$\chi_{\min}^2 = \min(\chi_1^2, \ldots, \chi_T^2), \tag{7}$$

i.e., which interval has the smallest error, in a chi-squared sense.

3.2. PERCEPTIBILITY

Earthquake perceptibility is defined to be the probability that a site perceives ground shaking at least of intensity I arising from, i.e., conditional on, an earthquake occurrence of magnitude M (Burton, 1978, 1990), i.e.:

$$P(I \mid M) = P_c(I)P_e(M). \tag{8}$$

The term $P_c(I)$ estimates the probability of perceiving intensity level I from a magnitude M earthquake, will increase with magnitude, and can be considered as a ratio of the felt area at intensity I or greater to that of the given area investigated. The felt area at intensity I can be obtained from the local macroseismic attenuation relationship. Papazachos and Papaioannou (1997), on the basis of macroseismic field investigation of the shallow earthquakes in the Balkan area using a large sample of macroseismic data, suggested that the macroseismic intensity at a site is a result of anisotropic radiation at the seismic source, geometrical spreading and anelastic attenuation along the wave path. They suggested the following attenuation relation for shallow earthquakes:

$$I = 1.43M - 3.59\log(R + 6) + 2.26, \tag{9}$$

where I is the intensity on the MM scale, M is the corresponding moment magnitude and R the epicentral distance in kilometer (Papaioannou and Papazachos, 2000). The term $P_e(M)$ is the derivative (probability density) of the third asymptotic law (2) and estimates the probability of a magnitude M occurrence. The magnitude which is most probably felt at a site at intensity level I or higher corresponds to the largest value of Equation (8) (Figure 3), i.e., where:

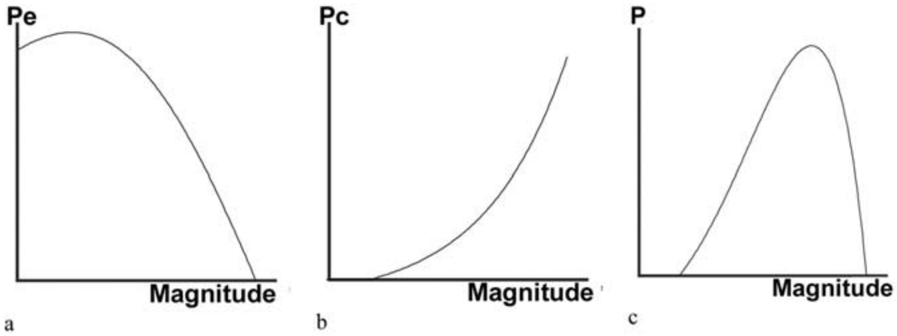


Figure 3. The definition of perceptibility: (a) the probability density curve of the Gumbel III model [$P_e(M)$ in (8)], (b) the probability of perceiving or feeling intensity I or greater when a magnitude M earthquake has occurred [$P_c(I)$) in (8)] and (c) the perceptibility curve [$P(I \mid M)$ in (8)].

$$\frac{d[P(I \mid M)]}{dM} = 0. \qquad (10)$$

This is the condition that defines the "most perceptible earthquake". In other words, this determines the earthquake that is most likely to be perceived or felt at any level of ground motion at a site or in a region and is therefore a characteristic property of the region (Burton, 1990).

3.3. THE MOST PROBABLE MAGNITUDE

The most expected extreme magnitude of a T-year interval is the one where the corresponding probability density is largest, i.e., $\frac{d^2\mathrm{GIII}^T(\omega,\mu,\lambda)}{dm^2} = 0$ from which it follows that:

$$m_T = \omega - (\omega - \mu)[(1 - \lambda)/T]^{\lambda}. \qquad (11)$$

And the earthquake with probability P of being a maximum or not being exceeded in a T-year interval can be obtained from Equation (3):

$$m_T(P) = \omega - (\omega - \mu)[- \ln P)/T]^{\lambda}. \qquad (12)$$

The magnitude error σ_m, however, can be estimated from the following equation:

$$\sigma_m^2 = \sigma_\omega^2 \left(\frac{\partial M}{\partial \omega}\right)^2 + \sigma_\mu^2 \left(\frac{\partial M}{\partial \mu}\right)^2 + \sigma_\lambda^2 \left(\frac{\partial M}{\partial \lambda}\right)^2 + 2\sigma_{\omega\mu}^2 \left(\frac{\partial M}{\partial \omega}\right)\left(\frac{\partial M}{\partial \mu}\right) + \cdots, \qquad (13)$$

where $\frac{\partial M}{\partial \omega}$, $\frac{\partial M}{\partial \mu}$ and $\frac{\partial M}{\partial \lambda}$ are the partial derivatives of Equation (1), and σ_ω, σ_μ and σ_λ the square root of the diagonal elements of the covariance matrix (Burton, 1979; Burton and Makropoulos, 1985; Makropoulos and Burton, 1985).

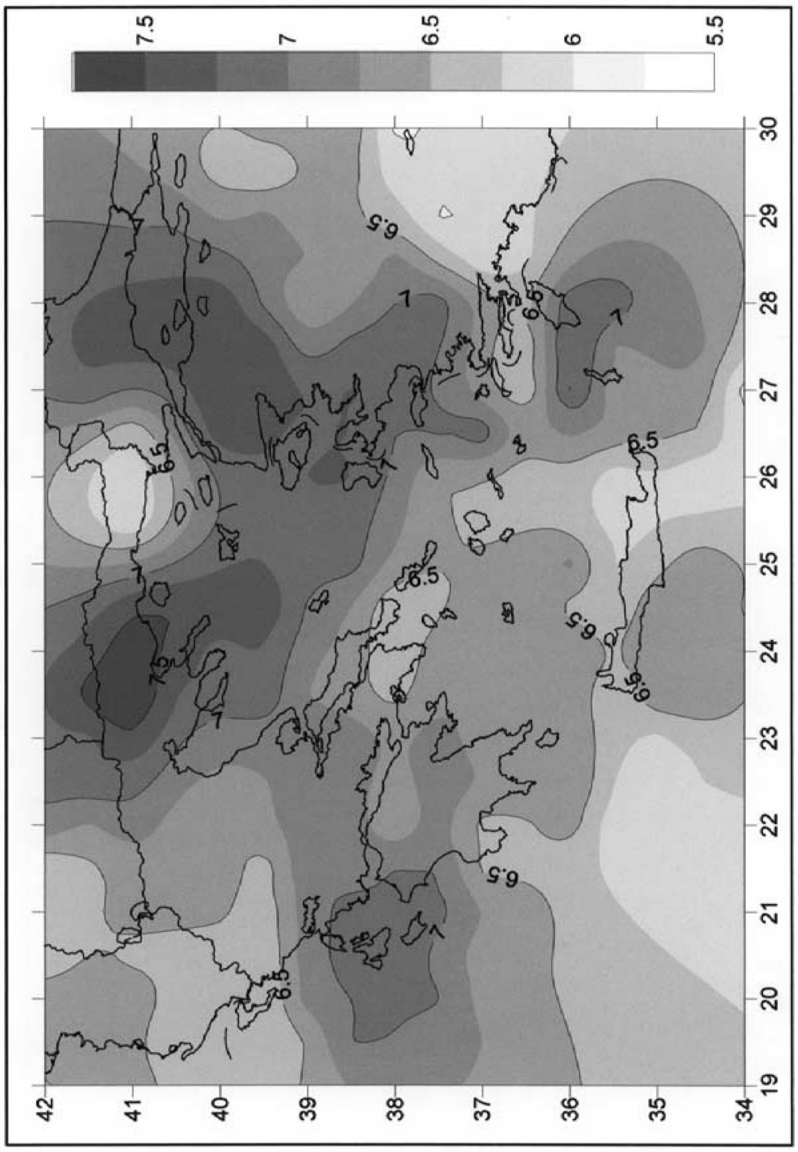
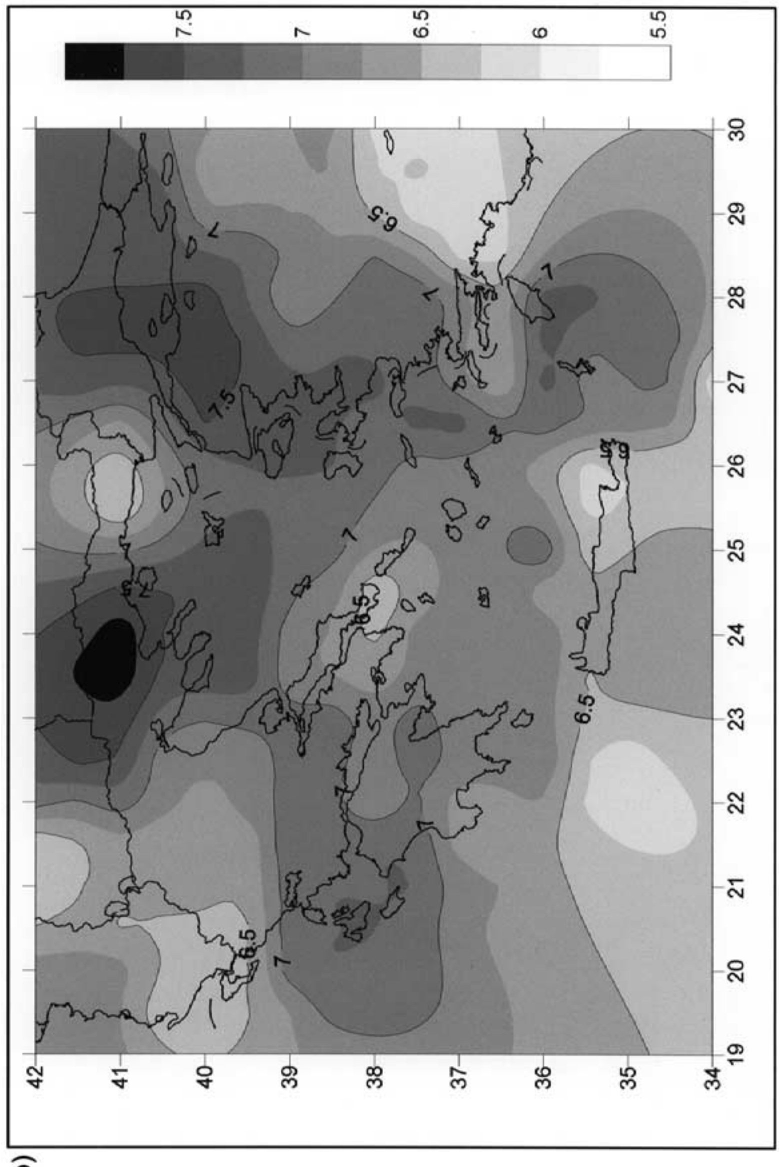


Figure 4. The largest magnitude expected over the time period of 50 (a), 100 (b) and 200 (c) years.



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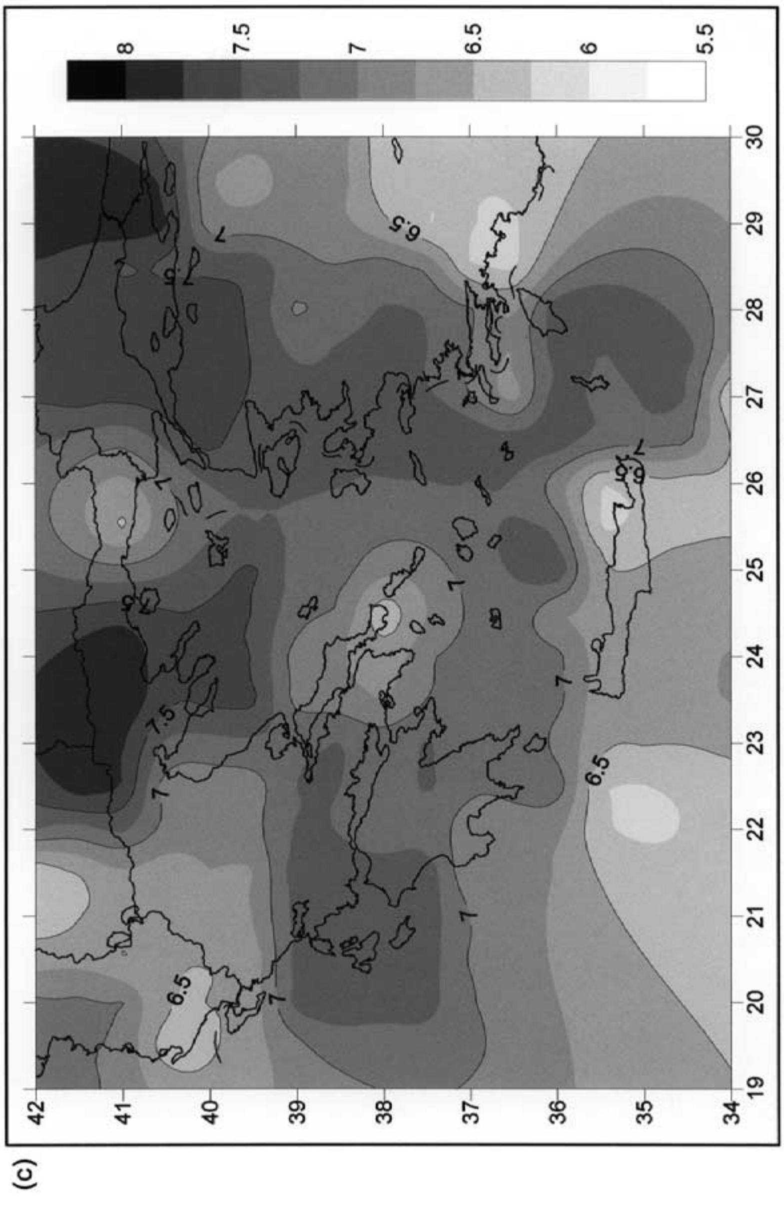

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(a)

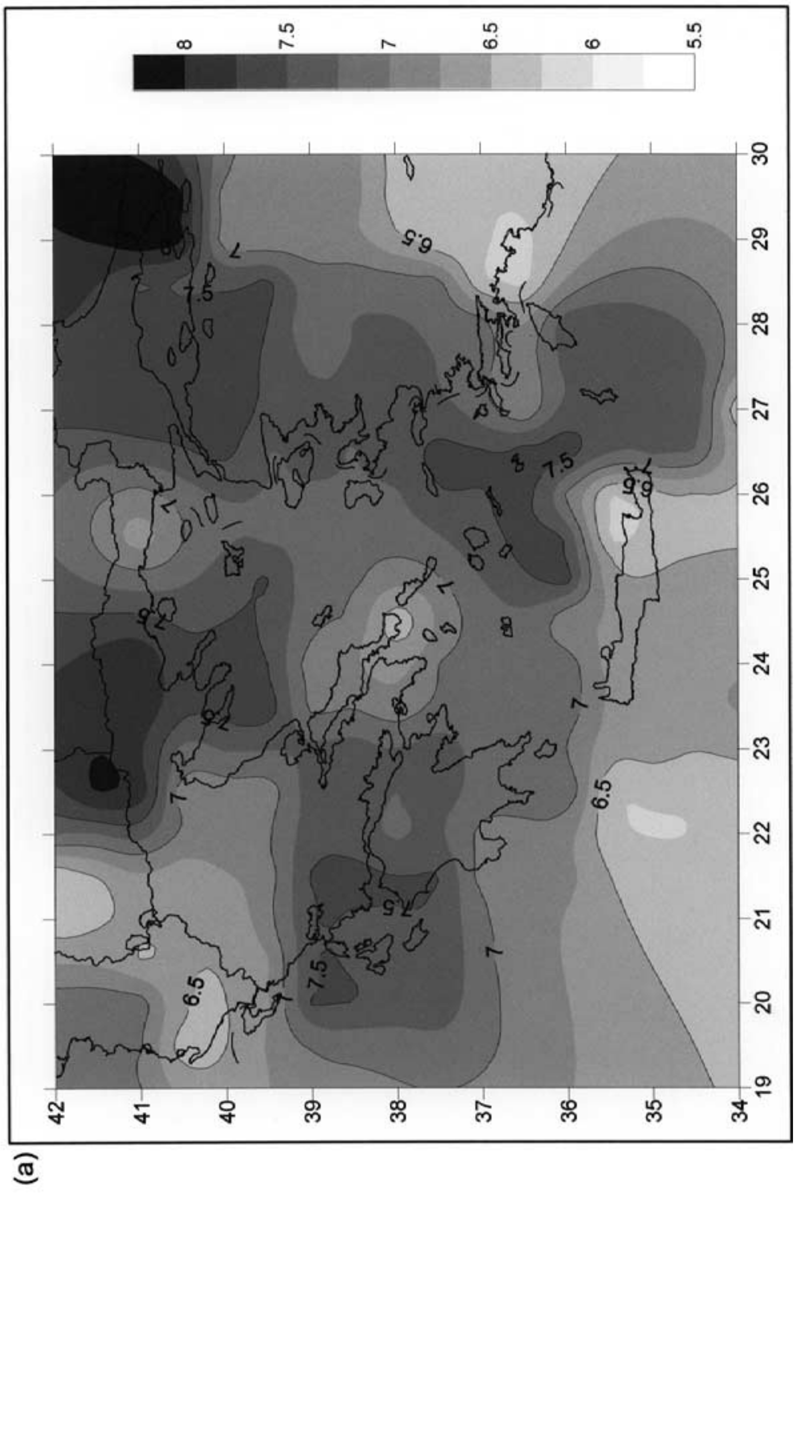
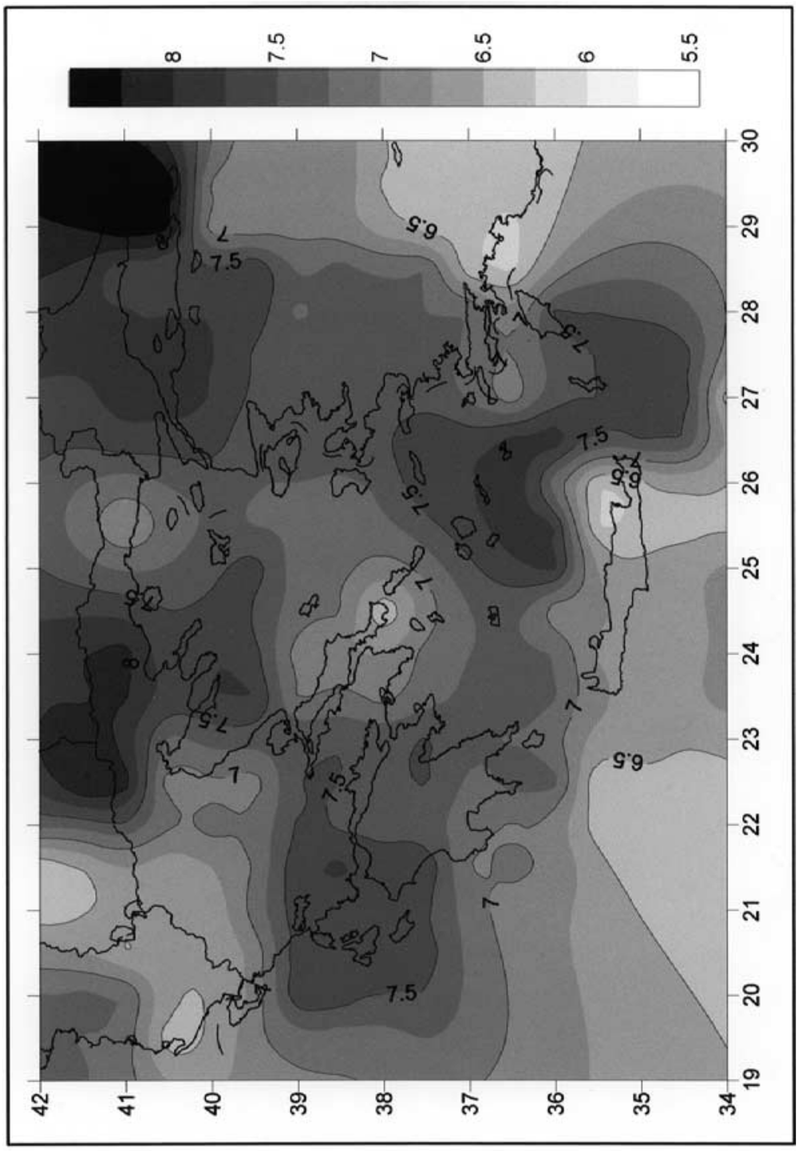


Figure 5. The magnitude expected with a non-exceedance probability of 90% (1 in 10 chance of exceedance) over the time period of 50 (a), 100 (b) and 200 (c) years.

(b)



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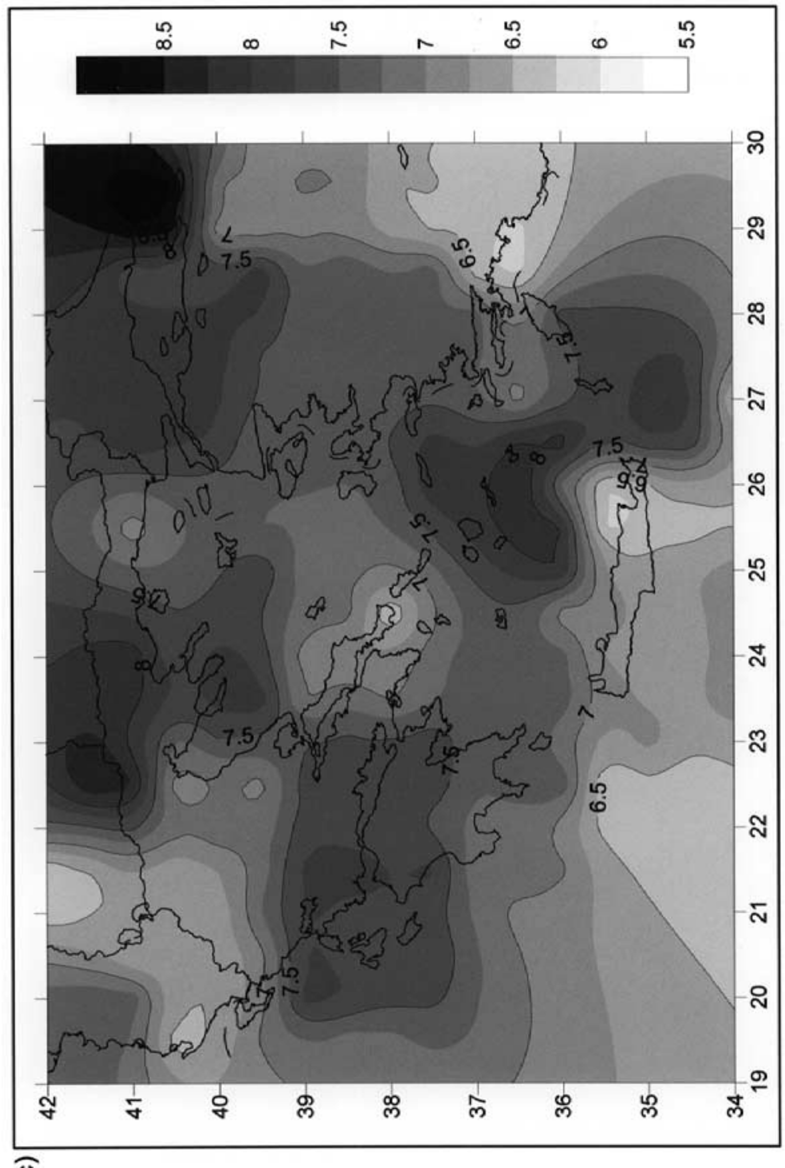

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Table I. ω, σ_ω, μ, σ_μ, λ, σ_λ are the three parameters of the Gumbel III model and the corresponding errors and $\sigma_{\omega\mu}$, $\sigma_{\omega\lambda}$ and $\sigma_{\mu\lambda}$ are the corresponding covariances of the parameters. $\mathbf{M_{max}}$ is the maximum earthquake observed in the cell. $\mathbf{M_{50}}$, $\mathbf{M_{100}}$, $\mathbf{M_{200}}$ and $\mathbf{M_{p50}}$, $\mathbf{M_{p100}}$, $\mathbf{M_{p200}}$ are the maximum magnitude and the magnitude with 90% probability of being a maximum (1 in 10 chance of being exceeded) in the next 50, 100 and 200-years respectively. $\sigma_{\mathbf{M}}$ and $\sigma_{\mathbf{Mp}}$ are the uncertainties on these magnitude forecasts.

Lat.	Long.	ω	μ	λ	σ_ω	σ_μ	σ_λ	$\sigma_{\omega\mu}$	$\sigma_{\omega\lambda}$	$\sigma_{\mu\lambda}$	$\mathbf{M_{max}}$	$\mathbf{M_{50}}$	$\mathbf{M_{100}}$	$\mathbf{M_{200}}$	$\sigma_{\mathbf{M}}$	$\mathbf{M_{p50}}$	$\mathbf{M_{p100}}$	$\mathbf{M_{p200}}$	$\sigma_{\mathbf{Mp}}$
34.0	23.5	7.01	1.16	0.53	1.20	9.00	0.77	10.00	−0.90	−6.87	6.6	6.51	6.66	6.77	0.28	6.78	6.85	6.90	0.73
34.0	24.0	6.90	−2.96	0.67	0.93	18.13	0.79	15.42	−0.70	−14.26	6.6	6.55	6.68	6.76	0.30	6.74	6.80	6.84	0.66
34.0	24.5	6.93	0.52	0.56	1.08	10.39	0.78	10.29	−0.81	−7.97	6.6	6.48	6.62	6.72	0.28	6.73	6.79	6.84	0.68
34.0	25.0	6.93	0.52	0.56	1.08	10.39	0.78	10.29	−0.81	−7.97	6.6	6.48	6.62	6.72	0.28	6.73	6.79	6.84	0.68
34.0	25.5	6.53	−0.33	0.67	0.86	15.92	1.03	12.44	−0.84	−16.22	6.3	6.29	6.38	6.44	0.31	6.42	6.46	6.49	0.62
34.0	26.0	6.65	1.39	0.53	1.26	10.46	0.96	12.23	−1.18	−9.99	6.3	6.22	6.35	6.44	0.28	6.45	6.51	6.56	0.76
34.0	26.5	7.18	2.24	0.35	3.13	7.23	0.86	21.74	−2.66	−6.14	6.5	6.08	6.32	6.50	0.21	6.60	6.72	6.82	1.11
34.0	27.0	6.79	3.42	0.31	3.27	5.22	1.01	16.39	−3.29	−5.23	6.5	5.91	6.08	6.22	0.00	6.30	6.40	6.48	1.03
34.5	22.5	6.33	0.52	0.78	0.63	19.75	1.46	11.00	−0.86	−28.61	6.2	6.25	6.28	6.30	0.33	6.28	6.30	6.31	0.51
34.5	23.0	6.62	2.56	0.59	0.74	5.82	0.79	3.84	−0.55	−4.51	6.5	6.38	6.46	6.51	0.27	6.51	6.55	6.57	0.52
34.5	23.5	6.70	−0.07	0.88	0.34	8.03	0.64	2.26	−0.20	−5.08	6.6	6.67	6.68	6.69	0.27	6.67	6.68	6.69	0.31
34.5	24.0	6.68	−2.76	0.97	0.33	13.41	0.71	3.64	−0.21	−9.35	6.6	6.67	6.68	6.68	0.29	6.66	6.67	6.67	0.31
34.5	24.5	6.71	−0.55	0.88	0.35	7.92	0.59	2.23	−0.18	−4.64	6.6	6.67	6.69	6.70	0.27	6.68	6.69	6.70	0.32
34.5	25.0	6.72	0.28	0.80	0.40	7.24	0.61	2.44	−0.22	−4.33	6.6	6.65	6.68	6.70	0.28	6.67	6.69	6.71	0.35
34.5	25.5	6.42	1.82	0.69	0.56	7.58	0.86	3.73	−0.46	−6.43	6.3	6.29	6.34	6.37	0.29	6.36	6.38	6.40	0.45
34.5	26.0	7.22	4.38	0.22	3.87	1.72	0.63	6.25	−2.43	−1.05	6.3	6.08	6.24	6.38	0.18	6.48	6.59	6.68	0.87
34.5	26.5	8.96	3.41	0.19	5.02	1.72	0.34	8.17	−1.72	−0.58	7.2	6.47	6.78	7.06	0.32	7.28	7.49	7.68	0.96
34.5	27.0	8.55	2.48	0.28	2.79	2.45	0.34	6.46	−0.93	−0.81	7.2	6.66	6.99	7.26	0.10	7.44	7.63	7.79	0.83
34.5	27.5	8.08	0.15	0.41	1.64	5.13	0.39	7.90	−0.62	−1.95	7.2	6.81	7.12	7.36	0.22	7.45	7.61	7.73	0.78
35.0	22.5	6.80	4.43	0.26	3.47	2.71	0.96	8.87	−3.32	−2.55	6.2	6.00	6.13	6.24	0.21	6.32	6.40	6.46	0.93
35.0	23.0	7.33	4.26	0.24	3.37	2.01	0.61	6.36	−2.04	−1.20	6.5	6.21	6.38	6.52	0.29	6.63	6.74	6.83	0.87
35.0	23.5	6.75	0.24	0.80	0.39	6.51	0.55	2.13	−0.20	−3.55	6.6	6.67	6.71	6.72	0.27	6.70	6.72	6.73	0.34
35.0	24.0	6.68	−2.76	0.97	0.33	13.41	0.71	3.64	−0.21	−9.35	6.6	6.67	6.68	6.68	0.29	6.66	6.67	6.67	0.31
35.0	24.5	6.71	−0.55	0.88	0.35	7.92	0.59	2.23	−0.18	−4.64	6.6	6.67	6.69	6.70	0.27	6.68	6.69	6.70	0.32
35.0	25.5	6.51	3.43	0.51	0.83	3.81	0.77	2.85	−0.61	−2.86	6.3	6.23	6.31	6.37	0.26	6.38	6.42	6.45	0.54

Table I. Continued

Lat.	Long.	ω	μ	λ	σ_ω	σ_μ	σ_λ	$\sigma_{\omega\mu}$	$\sigma_{\omega\lambda}$	$\sigma_{\mu\lambda}$	$\mathbf{M_{max}}$	$\mathbf{M_{50}}$	$\mathbf{M_{100}}$	$\mathbf{M_{200}}$	$\sigma_\mathbf{M}$	$\mathbf{M_{p50}}$	$\mathbf{M_{p100}}$	$\mathbf{M_{p200}}$	$\sigma_\mathbf{Mp}$
35.0	26.0	6.55	3.51	0.49	0.88	3.25	0.69	2.55	−0.59	−2.21	6.3	6.22	6.32	6.38	0.26	6.40	6.44	6.47	0.55
35.0	26.5	8.59	3.03	0.24	3.72	2.37	0.38	8.33	−1.41	−0.88	7.2	6.56	6.88	7.14	0.26	7.33	7.52	7.69	0.93
35.0	27.0	8.55	2.48	0.28	2.79	2.45	0.34	6.46	−0.93	−0.81	7.2	6.66	6.99	7.26	0.10	7.44	7.63	7.79	0.83
35.0	27.5	8.08	0.15	0.41	1.64	5.13	0.39	7.90	−0.62	−1.95	7.2	6.81	7.12	7.36	0.22	7.45	7.61	7.73	0.78
35.5	22.0	6.49	2.79	0.49	1.49	9.16	1.25	12.78	−1.82	−11.33	6.2	6.09	6.21	6.29	0.27	6.31	6.36	6.40	0.81
35.5	22.5	6.28	0.26	0.91	0.38	13.33	1.08	4.14	−0.36	−14.21	6.2	6.26	6.27	6.27	0.30	6.26	6.27	6.27	0.34
35.5	23.0	6.79	3.66	0.44	1.05	2.90	0.64	2.72	−0.65	−1.79	6.5	6.36	6.47	6.56	0.26	6.58	6.64	6.68	0.59
35.5	23.5	7.28	4.35	0.26	2.24	1.29	0.46	2.67	−1.01	−0.57	6.5	6.30	6.46	6.60	0.26	6.69	6.79	6.87	0.71
35.5	24.0	6.80	2.60	0.55	0.74	4.08	0.59	2.69	−0.42	−2.35	6.5	6.48	6.58	6.65	0.26	6.66	6.70	6.73	0.51
35.5	24.5	7.18	3.81	0.32	1.70	1.89	0.47	2.96	−0.79	−0.86	6.5	6.34	6.51	6.64	0.21	6.72	6.81	6.88	0.67
35.5	25.0	7.04	3.32	0.35	2.08	3.91	0.70	7.66	−1.45	−2.71	6.5	6.23	6.41	6.55	0.15	6.61	6.71	6.78	0.82
35.5	25.5	6.23	−0.76	0.82	0.63	26.29	1.55	14.62	−0.91	−40.44	6.1	6.16	6.19	6.21	0.35	6.19	6.21	6.22	0.52
35.5	26.0	6.29	2.64	0.64	0.64	6.60	0.97	3.72	−0.58	−6.29	6.1	6.14	6.19	6.23	0.28	6.22	6.25	6.26	0.48
35.5	26.5	8.11	1.90	0.33	2.45	4.31	0.46	9.99	−1.11	−1.94	7.2	6.64	6.95	7.19	0.20	7.32	7.48	7.61	0.89
35.5	27.0	8.49	3.48	0.23	2.88	1.37	0.29	3.67	−0.84	−0.39	7.2	6.61	6.90	7.14	0.16	7.31	7.49	7.64	0.75
35.5	27.5	8.09	2.28	0.33	1.84	2.57	0.34	4.41	−0.61	−0.84	7.2	6.72	7.00	7.23	0.20	7.35	7.50	7.62	0.73
35.5	28.0	7.65	−6.75	0.66	0.95	18.78	0.56	16.45	−0.51	−10.41	7.2	7.13	7.32	7.44	0.31	7.41	7.50	7.55	0.68
36.0	21.0	6.99	0.47	0.52	1.29	10.20	0.76	12.32	−0.96	−7.71	6.7	6.42	6.60	6.72	0.25	6.73	6.81	6.87	0.75
36.0	21.5	7.40	3.04	0.33	2.51	4.26	0.65	10.13	−1.61	−2.72	6.7	6.35	6.56	6.74	0.22	6.83	6.95	7.04	0.90
36.0	22.0	7.00	1.33	0.57	0.83	6.13	0.59	4.56	−0.46	−3.54	6.7	6.61	6.74	6.82	0.27	6.83	6.88	6.92	0.56
36.0	22.5	7.69	2.20	0.40	1.43	3.58	0.43	4.75	−0.60	−1.50	7.0	6.76	6.99	7.16	0.25	7.23	7.34	7.43	0.70
36.0	23.0	7.27	3.05	0.44	0.87	1.94	0.35	1.51	−0.30	−0.66	7.0	6.68	6.84	6.95	0.24	6.99	7.06	7.12	0.51
36.0	23.5	7.69	2.92	0.36	1.75	3.14	0.46	5.11	−0.80	−1.42	7.0	6.68	6.90	7.08	0.20	7.16	7.28	7.37	0.73
36.0	24.0	7.56	2.50	0.40	1.31	3.04	0.41	3.68	−0.53	−1.22	7.0	6.71	6.91	7.07	0.23	7.14	7.24	7.32	0.65
36.0	24.5	7.02	1.17	0.50	1.17	6.92	0.63	7.51	−0.72	−4.32	6.5	6.45	6.62	6.74	0.25	6.76	6.84	6.89	0.69
36.0	25.0	8.43	−1.22	0.40	2.40	8.78	0.49	20.14	−1.15	−4.22	7.4	6.81	7.20	7.50	0.27	7.62	7.82	7.97	1.03
36.0	25.5	9.90	2.47	0.18	9.46	3.70	0.47	34.03	−4.46	−1.73	7.4	6.40	6.82	7.18	0.23	7.49	7.78	8.03	1.38
36.0	26.0	7.83	3.53	0.26	2.59	1.73	0.38	4.20	−0.98	−0.64	7.4	6.41	6.64	6.84	0.15	6.97	7.12	7.23	0.77

Table I. Continued

Lat.	Long.	ω	μ	λ	σ_ω	σ_μ	σ_λ	$\sigma_{\omega\mu}$	$\sigma_{\omega\lambda}$	$\sigma_{\mu\lambda}$	$\mathbf{M_{max}}$	$\mathbf{M_{50}}$	$\mathbf{M_{100}}$	$\mathbf{M_{200}}$	$\sigma_{\mathbf{M}}$	$\mathbf{M_{p50}}$	$\mathbf{M_{p100}}$	$\mathbf{M_{p200}}$	$\sigma_{\mathbf{Mp}}$
36.0	26.5	9.57	3.57	0.19	3.92	0.99	0.22	3.62	−0.87	−0.21	7.4	6.80	7.14	7.44	0.22	7.69	7.92	8.12	0.78
36.0	27.0	7.43	−8.05	0.83	0.54	18.20	0.52	8.47	−0.26	−9.44	7.2	7.29	7.35	7.38	0.33	7.33	7.38	7.40	0.46
36.0	27.5	7.43	−8.05	0.83	0.54	18.20	0.52	8.47	−0.26	−9.44	7.2	7.29	7.35	7.38	0.33	7.33	7.38	7.40	0.46
36.0	28.0	7.69	−3.32	0.62	0.82	9.57	0.43	7.08	−0.33	−4.02	7.2	7.16	7.34	7.46	0.29	7.45	7.53	7.59	0.58
36.5	21.0	7.02	2.91	0.51	0.71	2.61	0.43	1.63	−0.30	−1.11	6.7	6.64	6.75	6.83	0.25	6.85	6.90	6.93	0.48
36.5	21.5	7.77	4.21	0.24	2.83	1.37	0.41	3.62	−1.15	−0.55	6.7	6.45	6.65	6.82	0.28	6.94	7.07	7.18	0.77
36.5	22.0	7.40	3.75	0.32	1.93	2.15	0.48	3.83	−0.91	−1.01	6.7	6.46	6.64	6.79	0.27	6.88	6.98	7.06	0.74
36.5	22.5	7.77	2.94	0.35	2.12	4.10	0.55	8.17	−1.16	−2.23	7.0	6.70	6.93	7.11	0.19	7.20	7.33	7.42	0.81
36.5	23.0	7.69	2.24	0.36	1.82	3.49	0.43	5.93	−0.78	−1.49	7.0	6.56	6.81	7.00	0.23	7.10	7.23	7.33	0.77
36.5	23.5	7.77	−1.63	0.46	1.83	10.44	0.55	18.16	−0.99	−5.72	7.0	6.62	6.94	7.17	0.22	7.23	7.38	7.49	0.92
36.5	26.0	10.04	1.46	0.20	9.11	5.09	0.49	45.22	−4.45	−2.47	7.4	6.33	6.81	7.23	0.20	7.57	7.89	8.17	1.49
36.5	26.5	9.16	2.43	0.24	4.23	2.65	0.35	10.70	−1.46	−0.91	7.4	6.65	7.03	7.35	0.30	7.59	7.83	8.03	1.02
36.5	27.0	7.28	3.47	0.31	2.17	2.54	0.52	5.16	−1.12	−1.29	6.7	6.27	6.47	6.62	0.14	6.72	6.83	6.91	0.76
36.5	27.5	7.58	3.15	0.29	3.43	4.32	0.69	14.18	−2.34	−2.92	6.7	6.31	6.54	6.73	0.09	6.85	6.99	7.09	1.01
36.5	28.0	6.98	1.70	0.49	1.19	6.04	0.63	6.61	−0.73	−3.76	6.7	6.41	6.57	6.69	0.27	6.72	6.79	6.85	0.69
36.5	28.5	6.19	−3.95	0.99	0.49	49.48	1.88	20.85	−0.84	−92.71	6.2	6.19	6.19	6.19	0.40	6.17	6.18	6.18	0.44
36.5	29.0	6.23	−3.82	0.94	0.53	41.20	1.60	19.19	−0.79	−65.69	6.2	6.21	6.22	6.22	0.38	6.20	6.21	6.22	0.47
37.0	19.5	7.31	−1.27	0.57	1.11	11.69	0.64	11.96	−0.69	−7.43	6.9	6.75	6.93	7.06	0.30	7.06	7.14	7.20	0.71
37.0	20.0	7.49	2.55	0.40	1.27	2.98	0.41	3.45	−0.51	−1.20	6.9	6.67	6.87	7.02	0.25	7.08	7.18	7.26	0.64
37.0	20.5	7.67	3.82	0.30	1.95	1.82	0.41	3.25	−0.79	−0.72	6.9	6.60	6.80	6.96	0.21	7.06	7.17	7.27	0.70
37.0	21.0	7.36	4.17	0.37	1.17	1.66	0.44	1.71	−0.50	−0.70	6.9	6.74	6.88	6.99	0.25	7.04	7.11	7.17	0.58
37.0	21.5	7.54	4.52	0.25	1.83	0.68	0.30	1.10	−0.55	−0.19	6.7	6.46	6.63	6.77	0.21	6.88	6.98	7.07	0.59
37.0	22.0	7.68	4.18	0.25	2.75	1.51	0.44	3.84	−1.19	−0.64	6.7	6.44	6.63	6.80	0.27	6.92	7.04	7.14	0.79
37.0	22.5	7.49	2.86	0.41	1.15	2.54	0.39	2.63	−0.44	−0.96	7.0	6.72	6.91	7.05	0.23	7.11	7.20	7.27	0.59
37.0	23.0	7.66	1.44	0.40	1.70	4.78	0.47	7.63	−0.78	−2.20	7.0	6.59	6.85	7.04	0.22	7.12	7.25	7.35	0.77
37.0	26.0	9.02	2.15	0.24	4.67	3.46	0.41	15.52	−1.90	−1.39	7.4	6.53	6.91	7.24	0.37	7.47	7.71	7.91	1.10
37.0	26.5	7.84	−0.19	0.53	0.91	5.35	0.37	4.38	−0.33	−1.97	7.4	7.15	7.36	7.51	0.26	7.53	7.62	7.69	0.58
37.0	27.0	7.66	3.44	0.33	1.56	1.68	0.35	2.38	−0.53	−0.56	7.0	6.63	6.84	7.00	0.24	7.10	7.21	7.30	0.65

Table I. Continued

Lat.	Long.	ω	μ	λ	σ_ω	σ_μ	σ_λ	$\sigma_{\omega\mu}$	$\sigma_{\omega\lambda}$	$\sigma_{\mu\lambda}$	$\mathbf{M_{max}}$	$\mathbf{M_{50}}$	$\mathbf{M_{100}}$	$\mathbf{M_{200}}$	$\sigma_\mathbf{M}$	$\mathbf{M_{p50}}$	$\mathbf{M_{p100}}$	$\mathbf{M_{p200}}$	$\sigma_\mathbf{Mp}$
37.0	27.5	7.69	3.74	0.31	1.66	1.43	0.34	2.15	−0.56	−0.47	7.0	6.62	6.83	6.99	0.22	7.09	7.21	7.30	0.64
37.0	28.0	7.64	2.58	0.37	1.52	2.90	0.40	4.05	−0.60	−1.15	7.0	6.66	6.88	7.05	0.26	7.14	7.25	7.34	0.70
37.0	28.5	6.49	3.51	0.43	1.54	5.73	1.10	8.25	−1.66	−6.23	6.2	6.06	6.17	6.25	0.24	6.28	6.34	6.38	0.77
37.0	29.0	6.56	3.13	0.43	2.00	8.30	1.29	15.80	−2.55	−10.60	6.2	6.05	6.18	6.28	0.16	6.31	6.38	6.42	0.92
37.5	19.5	7.44	0.60	0.53	0.88	4.96	0.42	3.97	−0.35	−2.03	6.9	6.86	7.04	7.16	0.26	7.18	7.26	7.31	0.57
37.5	20.0	7.79	3.54	0.39	0.83	0.96	0.22	0.69	−0.18	−0.21	7.3	7.02	7.20	7.34	0.23	7.40	7.49	7.56	0.46
37.5	20.5	8.22	4.27	0.27	1.44	0.61	0.21	0.76	−0.29	−0.12	7.3	6.95	7.17	7.35	0.22	7.47	7.60	7.70	0.54
37.5	21.0	7.84	4.01	0.37	0.94	1.01	0.26	0.81	−0.24	−0.25	7.3	7.07	7.24	7.38	0.23	7.44	7.53	7.60	0.49
37.5	21.5	8.41	4.32	0.25	1.57	0.52	0.19	0.71	−0.29	−0.09	7.3	6.98	7.21	7.40	0.20	7.53	7.67	7.79	0.54
37.5	22.0	7.84	4.17	0.30	1.30	0.83	0.26	0.94	−0.33	−0.20	7.2	6.84	7.03	7.18	0.22	7.28	7.38	7.47	0.54
37.5	22.5	8.10	4.32	0.28	1.60	0.83	0.26	1.13	−0.41	−0.20	7.2	6.93	7.13	7.30	0.25	7.41	7.53	7.63	0.60
37.5	23.0	8.19	4.20	0.26	1.61	0.69	0.22	0.97	−0.36	−0.15	7.2	6.87	7.09	7.28	0.22	7.40	7.53	7.64	0.57
37.5	23.5	7.46	3.46	0.38	1.12	1.58	0.34	1.59	−0.37	−0.52	7.0	6.69	6.86	7.00	0.23	7.06	7.15	7.22	0.56
37.5	24.0	7.33	1.92	0.46	1.11	4.14	0.47	4.21	−0.51	−1.91	7.0	6.67	6.85	6.98	0.25	7.02	7.10	7.17	0.63
37.5	26.0	9.16	2.23	0.23	5.18	3.35	0.41	16.67	−2.10	−1.35	7.4	6.51	6.90	7.23	0.26	7.48	7.73	7.94	1.13
37.5	26.5	8.16	1.77	0.39	1.34	2.82	0.31	3.47	−0.41	−0.86	7.4	7.03	7.30	7.50	0.22	7.59	7.73	7.83	0.65
37.5	27.0	7.61	1.29	0.49	0.89	3.54	0.35	2.83	−0.30	−1.23	7.0	6.95	7.14	7.28	0.26	7.31	7.39	7.46	0.55
37.5	27.5	7.44	−0.24	0.60	0.67	5.31	0.39	3.15	−0.25	−2.02	7.0	7.02	7.16	7.26	0.27	7.25	7.32	7.36	0.49
37.5	28.0	7.30	−2.55	0.75	0.52	9.40	0.48	4.22	−0.23	−4.47	7.0	7.11	7.19	7.23	0.30	7.20	7.24	7.27	0.43
37.5	28.5	7.88	1.65	0.34	2.87	5.54	0.56	15.20	−1.58	−3.05	7.0	6.42	6.72	6.96	0.27	7.09	7.26	7.39	1.03
37.5	29.0	6.79	4.15	0.27	3.67	3.76	1.07	13.18	−3.88	−3.94	6.2	5.97	6.11	6.23	0.42	6.31	6.39	6.46	1.07
37.5	29.5	6.64	1.51	0.51	1.52	12.02	1.11	17.21	−1.65	−13.27	6.4	6.16	6.30	6.40	0.23	6.42	6.49	6.53	0.85
38.0	19.5	7.21	0.14	0.68	0.51	5.21	0.42	2.30	−0.20	−2.16	6.9	6.98	7.07	7.12	0.27	7.10	7.14	7.17	0.41
38.0	20.0	7.83	4.02	0.36	0.79	0.56	0.19	0.38	−0.14	−0.10	7.3	7.02	7.20	7.34	0.22	7.41	7.50	7.57	0.43
38.0	20.5	7.73	3.76	0.41	0.77	1.10	0.26	0.72	−0.19	−0.27	7.3	7.09	7.25	7.37	0.23	7.41	7.49	7.55	0.45
38.0	21.0	8.01	4.34	0.31	1.27	0.91	0.27	1.00	−0.33	−0.23	7.3	7.04	7.23	7.38	0.23	7.47	7.57	7.66	0.54
38.0	21.5	8.24	4.29	0.27	1.40	0.61	0.21	0.75	−0.28	−0.12	7.3	7.00	7.21	7.39	0.22	7.51	7.63	7.74	0.53
38.0	22.0	8.82	4.57	0.16	4.33	0.57	0.25	2.24	−1.08	−0.13	7.2	6.57	6.80	7.01	0.25	7.19	7.36	7.51	0.72

Table I. Continued

Lat.	Long.	ω	μ	λ	σ_ω	σ_μ	σ_λ	$\sigma_{\omega\mu}$	$\sigma_{\omega\lambda}$	$\sigma_{\mu\lambda}$	$\mathbf{M_{max}}$	$\mathbf{M_{50}}$	$\mathbf{M_{100}}$	$\mathbf{M_{200}}$	$\sigma_\mathbf{M}$	$\mathbf{M_{p50}}$	$\mathbf{M_{p100}}$	$\mathbf{M_{p200}}$	$\sigma_\mathbf{Mp}$
38.0	22.5	8.80	4.59	0.16	3.97	0.56	0.24	1.99	−0.96	−0.13	7.2	6.62	6.85	7.06	0.19	7.24	7.40	7.55	0.68
38.0	23.0	8.36	4.48	0.20	2.58	0.62	0.25	1.42	−0.63	−0.14	7.2	6.69	6.91	7.10	0.19	7.26	7.40	7.53	0.62
38.0	23.5	7.31	4.24	0.29	1.81	1.41	0.44	2.32	−0.78	−0.60	6.6	6.42	6.58	6.72	0.23	6.80	6.89	6.97	0.65
38.0	24.0	7.13	4.10	0.30	2.59	3.00	0.76	7.30	−1.94	−2.22	6.5	6.30	6.45	6.58	0.26	6.66	6.75	6.82	0.88
38.0	24.5	6.30	−3.14	0.91	0.50	28.91	1.27	12.49	−0.58	−36.32	6.2	6.27	6.28	6.29	0.35	6.27	6.28	6.29	0.44
38.0	26.0	7.44	−2.15	0.61	0.84	9.31	0.48	7.08	−0.38	−4.39	7.0	6.94	7.11	7.23	0.28	7.22	7.29	7.34	0.59
38.0	26.5	7.67	1.05	0.50	0.87	3.58	0.34	2.82	−0.29	−1.20	7.0	7.00	7.19	7.33	0.25	7.36	7.45	7.51	0.55
38.0	27.0	7.41	−1.07	0.70	0.46	4.79	0.33	1.87	−0.14	−1.55	7.0	7.18	7.27	7.32	0.27	7.30	7.34	7.37	0.38
38.0	27.5	7.36	−0.15	0.68	0.49	4.68	0.37	1.96	−0.17	−1.68	7.0	7.12	7.21	7.27	0.27	7.25	7.29	7.32	0.40
38.0	28.0	7.48	−0.22	0.58	0.80	6.30	0.44	4.53	−0.34	−2.74	7.0	6.99	7.15	7.26	0.27	7.26	7.33	7.38	0.55
38.0	28.5	7.34	−2.83	0.61	0.97	13.21	0.59	11.82	−0.56	−7.78	7.0	6.83	7.01	7.12	0.29	7.11	7.19	7.24	0.66
38.0	29.0	6.69	0.23	0.61	0.90	11.16	0.82	9.14	−0.70	−9.00	6.5	6.36	6.48	6.55	0.28	6.54	6.59	6.63	0.62
38.0	29.5	6.67	2.63	0.44	1.69	7.00	0.95	11.14	−1.57	−6.57	6.4	6.10	6.25	6.36	0.26	6.40	6.47	6.52	0.84
38.0	30.0	6.93	3.00	0.33	3.62	7.08	1.09	24.74	−3.91	−7.61	6.4	5.96	6.16	6.32	0.33	6.40	6.51	6.59	1.18
38.5	19.5	7.16	−1.23	0.75	0.52	9.50	0.57	4.23	−0.27	−5.35	6.9	7.01	7.07	7.11	0.30	7.08	7.11	7.13	0.43
38.5	20.0	8.08	3.32	0.34	1.37	1.56	0.29	1.90	−0.39	−0.43	7.3	7.00	7.23	7.41	0.22	7.50	7.62	7.72	0.61
38.5	20.5	7.84	3.39	0.39	0.94	1.38	0.27	1.13	−0.25	−0.36	7.3	7.05	7.24	7.38	0.23	7.44	7.54	7.61	0.50
38.5	21.0	7.84	3.39	0.39	0.94	1.38	0.27	1.13	−0.25	−0.36	7.3	7.05	7.24	7.38	0.23	7.44	7.54	7.61	0.50
38.5	21.5	9.24	4.36	0.18	3.54	0.67	0.22	2.11	−0.77	−0.14	7.3	6.89	7.16	7.40	0.21	7.61	7.80	7.97	0.69
38.5	22.0	7.95	4.23	0.29	1.33	0.70	0.23	0.82	−0.30	−0.15	7.2	6.86	7.06	7.22	0.23	7.32	7.44	7.53	0.54
38.5	22.5	8.15	4.50	0.25	2.44	1.29	0.38	2.86	−0.91	−0.47	7.2	6.88	7.09	7.26	0.23	7.38	7.50	7.61	0.73
38.5	23.0	7.95	4.24	0.30	1.26	0.74	0.24	0.81	−0.30	−0.17	7.2	6.92	7.12	7.27	0.22	7.37	7.48	7.57	0.53
38.5	23.5	7.57	4.60	0.26	1.70	0.82	0.33	1.22	−0.56	−0.26	6.8	6.60	6.76	6.90	0.19	6.99	7.09	7.17	0.58
38.5	24.0	6.86	2.28	0.65	0.55	4.76	0.61	2.24	−0.32	−2.85	6.7	6.68	6.74	6.79	0.28	6.78	6.81	6.83	0.43
38.5	24.5	7.16	1.12	0.57	0.72	4.66	0.45	2.98	−0.31	−2.05	6.9	6.76	6.89	6.98	0.27	6.98	7.04	7.08	0.50
38.5	25.0	7.14	−19.48	0.96	0.53	46.29	0.67	21.17	−0.32	−30.88	6.9	7.11	7.12	7.13	0.39	7.07	7.10	7.12	0.47
38.5	26.0	7.26	−6.66	0.99	0.29	9.55	0.37	2.23	−0.09	−3.49	7.0	7.26	7.26	7.26	0.26	7.23	7.24	7.25	0.28
38.5	26.5	7.28	−4.47	0.92	0.31	7.42	0.35	1.85	−0.10	−2.59	7.0	7.25	7.26	7.27	0.26	7.24	7.26	7.27	0.29

Table I. Continued

Lat.	Long.	ω	μ	λ	σ_ω	σ_μ	σ_λ	$\sigma_{\omega\mu}$	$\sigma_{\omega\lambda}$	$\sigma_{\mu\lambda}$	$\mathbf{M_{max}}$	$\mathbf{M_{50}}$	$\mathbf{M_{100}}$	$\mathbf{M_{200}}$	$\sigma_{\mathbf{M}}$	$\mathbf{M_{p50}}$	$\mathbf{M_{p100}}$	$\mathbf{M_{p200}}$	$\sigma_{\mathbf{Mp}}$
38.5	27.0	7.29	−3.19	0.93	0.28	5.36	0.31	1.19	−0.08	−1.64	7.0	7.26	7.28	7.28	0.24	7.25	7.27	7.28	0.26
38.5	27.5	7.44	0.65	0.61	0.58	3.93	0.35	1.98	−0.19	−1.36	7.0	7.09	7.21	7.29	0.26	7.28	7.34	7.37	0.44
38.5	28.0	7.85	2.77	0.35	1.47	2.01	0.32	2.72	−0.46	−0.62	7.0	6.73	6.97	7.16	0.23	7.26	7.39	7.49	0.64
38.5	28.5	8.15	2.68	0.28	3.25	3.25	0.46	10.02	−1.48	−1.46	7.0	6.47	6.77	7.01	0.21	7.17	7.34	7.48	0.95
38.5	29.0	7.02	1.42	0.53	0.87	5.00	0.51	3.96	−0.43	−2.52	6.7	6.55	6.70	6.80	0.26	6.81	6.87	6.92	0.57
38.5	29.5	7.09	0.23	0.55	0.99	7.96	0.59	7.23	−0.57	−4.66	6.7	6.59	6.75	6.86	0.27	6.86	6.94	6.99	0.64
38.5	30.0	7.00	−3.07	0.68	0.78	14.78	0.66	10.45	−0.49	−9.64	6.7	6.68	6.80	6.88	0.30	6.85	6.91	6.94	0.58
39.0	19.5	7.63	2.90	0.34	1.84	2.57	0.41	4.40	−0.74	−1.03	6.9	6.52	6.75	6.93	0.25	7.03	7.15	7.25	0.74
39.0	20.0	8.60	3.71	0.25	2.21	1.02	0.24	2.03	−0.52	−0.23	7.3	6.86	7.13	7.36	0.25	7.53	7.69	7.84	0.67
39.0	20.5	8.33	3.75	0.27	1.80	1.08	0.25	1.74	−0.45	−0.26	7.3	6.90	7.15	7.35	0.25	7.49	7.63	7.76	0.64
39.0	21.0	8.40	3.86	0.26	1.98	1.05	0.26	1.87	−0.50	−0.26	7.3	6.89	7.14	7.35	0.24	7.49	7.64	7.77	0.65
39.0	21.5	8.36	4.05	0.27	1.78	0.97	0.25	1.55	−0.45	−0.23	7.3	6.98	7.22	7.41	0.19	7.54	7.68	7.80	0.61
39.0	22.0	8.18	4.21	0.27	1.66	0.77	0.24	1.15	−0.39	−0.18	7.2	6.89	7.11	7.29	0.21	7.41	7.54	7.65	0.58
39.0	22.5	8.13	4.65	0.25	1.58	0.52	0.22	0.70	−0.35	−0.11	7.2	6.91	7.10	7.26	0.19	7.38	7.50	7.60	0.53
39.0	23.0	7.90	4.95	0.26	1.35	0.43	0.23	0.48	−0.31	−0.09	7.2	6.91	7.07	7.21	0.20	7.30	7.40	7.48	0.50
39.0	23.5	7.07	3.89	0.49	0.55	1.10	0.32	0.51	−0.16	−0.33	6.8	6.74	6.84	6.90	0.23	6.92	6.96	6.99	0.38
39.0	24.0	6.89	1.50	0.811	0.34	4.61	0.52	1.25	−0.16	−2.36	6.8	6.83	6.86	6.87	0.25	6.85	6.87	6.88	0.30
39.0	24.5	7.15	−0.07	0.72	0.45	4.94	0.40	1.88	−0.16	−1.93	6.9	6.97	7.04	7.08	0.27	7.06	7.10	7.12	0.37
39.0	25.0	7.17	−12.34	0.87	0.57	30.46	0.63	15.35	−0.34	−19.17	6.9	7.06	7.11	7.14	0.36	7.08	7.12	7.14	0.49
39.0	26.0	7.28	−8.47	0.94	0.36	13.85	0.43	4.03	−0.13	−5.83	7.0	7.25	7.26	7.27	0.29	7.23	7.25	7.27	0.33
39.0	26.5	7.44	−2.91	0.72	0.50	6.94	0.36	2.97	−0.17	−2.45	7.0	7.20	7.29	7.35	0.28	7.32	7.37	7.40	0.41
39.0	27.5	7.55	0.51	0.50	0.96	4.65	0.39	4.06	−0.36	−1.77	7.0	6.86	7.06	7.21	0.26	7.23	7.33	7.39	0.59
39.0	28.0	7.76	2.97	0.31	2.29	2.85	0.45	6.14	−1.02	−1.26	7.0	6.50	6.75	6.94	0.19	7.06	7.20	7.31	0.81
39.0	28.5	7.42	−1.83	0.56	1.27	13.16	0.66	15.65	−0.81	−8.57	7.0	6.76	6.97	7.11	0.28	7.12	7.22	7.28	0.78
39.0	29.0	6.97	0.68	0.61	0.77	7.40	0.61	5.10	−0.45	−4.46	6.7	6.64	6.75	6.83	0.28	6.82	6.87	6.91	0.54
39.0	29.5	7.20	2.13	0.45	1.88	9.36	0.94	16.72	−1.74	−8.73	6.7	6.52	6.70	6.83	0.27	6.88	6.96	7.03	0.91
39.5	19.5	7.63	3.56	0.26	3.70	2.95	0.60	10.41	−2.19	−1.72	6.7	6.25	6.48	6.66	0.15	6.79	6.93	7.05	0.97
39.5	20.0	7.49	4.51	0.22	2.92	1.06	0.43	2.87	−1.25	−0.44	6.7	6.29	6.46	6.61	0.13	6.72	6.83	6.92	0.71

Table I. Continued

Lat.	Long.	ω	μ	λ	σ_ω	σ_μ	σ_λ	$\sigma_{\omega\mu}$	$\sigma_{\omega\lambda}$	$\sigma_{\mu\lambda}$	$\mathbf{M_{max}}$	$\mathbf{M_{50}}$	$\mathbf{M_{100}}$	$\mathbf{M_{200}}$	$\sigma_{\mathbf{M}}$	$\mathbf{M_{p50}}$	$\mathbf{M_{p100}}$	$\mathbf{M_{p200}}$	$\sigma_{\mathbf{Mp}}$
39.5	20.5	7.66	4.68	0.19	3.92	0.99	0.45	3.62	−1.76	−0.43	6.7	6.29	6.45	6.60	0.24	6.72	6.84	6.94	0.78
39.5	21.0	9.27	4.74	0.11	10.40	0.70	0.35	6.78	−3.60	−0.23	6.7	6.34	6.55	6.75	0.26	6.94	7.11	7.27	0.89
39.5	21.5	8.45	4.91	0.13	7.61	0.86	0.43	6.01	−3.28	−0.35	6.7	6.38	6.56	6.72	0.32	6.88	7.02	7.14	0.90
39.5	22.0	7.25	3.66	0.42	1.00	2.04	0.43	1.81	−0.42	−0.86	6.8	6.69	6.83	6.93	0.25	6.97	7.04	7.09	0.55
39.5	22.5	6.96	1.59	0.64	0.53	4.48	0.49	2.05	−0.25	−2.15	6.8	6.73	6.81	6.87	0.26	6.86	6.89	6.92	0.42
39.5	23.0	7.60	2.86	0.43	1.05	2.67	0.39	2.52	−0.40	−1.01	7.1	6.90	7.08	7.21	0.24	7.26	7.35	7.41	0.57
39.5	23.5	8.16	2.72	0.38	1.28	2.27	0.32	2.65	−0.40	−0.70	7.4	7.15	7.39	7.57	0.25	7.65	7.77	7.86	0.63
39.5	24.0	7.73	2.15	0.52	0.66	2.41	0.30	1.39	−0.19	−0.71	7.4	7.24	7.39	7.49	0.25	7.51	7.58	7.62	0.45
39.5	24.5	7.53	−6.61	0.87	0.39	11.50	0.40	3.75	−0.14	−4.55	7.4	7.45	7.48	7.50	0.29	7.46	7.49	7.51	0.35
39.5	25.0	7.77	−2.77	0.62	0.76	7.92	0.38	5.39	−0.28	−3.01	7.4	7.25	7.43	7.55	0.29	7.54	7.62	7.67	0.55
39.5	25.5	7.26	−6.48	0.91	0.40	14.49	0.51	4.76	−0.18	−7.28	7.0	7.22	7.24	7.25	0.31	7.21	7.23	7.25	0.36
39.5	26.5	7.27	−8.41	0.99	0.31	11.91	0.39	2.96	−0.11	−4.58	7.0	7.27	7.27	7.27	0.28	7.23	7.25	7.26	0.29
39.5	27.0	7.47	−4.31	0.92	0.31	6.76	0.33	1.66	−0.09	−2.19	7.4	7.44	7.45	7.46	0.26	7.43	7.45	7.46	0.28
39.5	27.5	7.50	−7.78	0.89	0.42	15.48	0.47	5.53	−0.18	−7.25	7.4	7.43	7.46	7.48	0.31	7.44	7.47	7.48	0.38
39.5	28.0	8.01	0.33	0.44	1.33	4.76	0.37	5.86	−0.48	−1.73	7.4	6.96	7.24	7.44	0.26	7.51	7.64	7.74	0.70
39.5	28.5	8.37	1.07	0.36	1.92	3.86	0.35	6.97	−0.66	−1.33	7.4	6.86	7.20	7.46	0.22	7.59	7.76	7.90	0.80
39.5	29.0	6.88	−3.34	0.86	0.42	12.06	0.57	4.24	−0.22	−6.84	6.7	6.81	6.84	6.86	0.30	6.83	6.85	6.86	0.37
39.5	29.5	7.46	3.52	0.29	2.97	3.19	0.62	8.99	−1.81	−1.93	6.7	6.30	6.51	6.68	0.27	6.79	6.91	7.01	0.94
39.5	30.0	6.93	−3.46	0.68	0.91	19.66	0.80	16.51	−0.70	−15.68	6.7	6.59	6.72	6.80	0.31	6.77	6.83	6.87	0.66
40.0	20.0	6.59	2.89	0.61	0.54	3.29	0.57	1.53	−0.29	−1.83	6.4	6.40	6.46	6.51	0.26	6.50	6.53	6.55	0.41
40.0	20.5	6.68	3.81	0.48	0.80	2.40	0.59	1.70	−0.46	−1.38	6.4	6.35	6.45	6.51	0.25	6.53	6.57	6.60	0.50
40.0	21.0	6.64	−0.20	0.81	0.42	8.91	0.67	3.14	−0.26	−5.92	6.5	6.57	6.60	6.62	0.29	6.59	6.61	6.63	0.37
40.0	21.5	6.78	1.69	0.75	0.39	4.45	0.53	1.43	−0.19	−2.32	6.7	6.69	6.72	6.75	0.26	6.73	6.75	6.76	0.34
40.0	22.0	7.75	4.30	0.25	2.55	1.28	0.40	2.96	−1.01	−0.49	6.8	6.52	6.71	6.88	0.26	6.99	7.11	7.21	0.75

Table I. Continued

Lat.	Long.	ω	μ	λ	σ_ω	σ_μ	σ_λ	$\sigma_{\omega\mu}$	$\sigma_{\omega\lambda}$	$\sigma_{\mu\lambda}$	$\mathbf{M_{max}}$	$\mathbf{M_{50}}$	$\mathbf{M_{100}}$	$\mathbf{M_{200}}$	$\sigma_{\mathbf{M}}$	$\mathbf{M_{p50}}$	$\mathbf{M_{p100}}$	$\mathbf{M_{p200}}$	$\sigma_{\mathbf{Mp}}$
40.0	23.0	7.98	4.85	0.24	2.04	0.79	0.32	1.38	−0.65	−0.23	7.1	6.84	7.02	7.17	0.23	7.28	7.38	7.48	0.63
40.0	23.5	8.09	2.47	0.41	1.11	2.34	0.30	2.32	−0.33	−0.69	7.4	7.17	7.39	7.56	0.24	7.63	7.74	7.83	0.58
40.0	24.0	8.15	3.81	0.34	1.38	1.55	0.32	1.91	−0.43	−0.47	7.4	7.16	7.37	7.53	0.23	7.62	7.73	7.82	0.61
40.0	24.5	7.62	−2.15	0.72	0.51	7.25	0.39	3.17	−0.18	−2.79	7.4	7.39	7.48	7.53	0.28	7.50	7.55	7.58	0.42
40.0	26.5	7.77	−8.16	0.72	0.69	15.01	0.42	9.30	−0.28	−6.28	7.3	7.38	7.53	7.62	0.31	7.58	7.65	7.70	0.54
40.0	27.0	7.84	−2.65	0.68	0.55	6.12	0.32	2.93	−0.16	−1.92	7.4	7.49	7.62	7.70	0.28	7.68	7.74	7.78	0.44
40.0	27.5	7.91	−4.18	0.65	0.76	10.36	0.41	7.07	−0.30	−4.22	7.4	7.42	7.60	7.71	0.29	7.69	7.77	7.82	0.56
40.0	28.0	7.87	4.06	0.66	0.72	10.14	0.41	6.50	−0.28	−4.13	7.4	7.43	7.59	7.69	0.29	7.67	7.74	7.79	0.54
40.0	28.5	7.73	−0.63	0.54	0.92	6.22	0.40	5.24	−0.36	−2.48	7.4	7.07	7.28	7.42	0.27	7.43	7.53	7.59	0.60
40.0	29.0	6.95	0.99	0.65	0.63	6.78	0.60	3.80	−0.36	−4.02	6.7	6.71	6.79	6.85	0.28	6.84	6.88	6.90	0.48
40.0	29.5	7.42	3.56	0.31	2.70	3.78	0.69	9.64	−1.83	−2.55	6.7	6.40	6.60	6.76	0.29	6.85	6.96	7.05	0.92
40.5	19.5	6.38	3.21	0.65	0.65	7.32	1.20	4.17	−0.73	−8.63	6.3	6.25	6.30	6.33	0.28	6.32	6.34	6.36	0.49
40.5	20.0	6.63	3.76	0.55	0.56	1.97	0.51	0.94	−0.27	−0.98	6.4	6.41	6.48	6.53	0.24	6.53	6.56	6.58	0.40
40.5	20.5	6.58	3.65	0.60	0.48	2.24	0.55	0.91	−0.25	−1.19	6.4	6.42	6.47	6.51	0.25	6.51	6.53	6.55	0.37
40.5	21.0	6.64	1.42	0.78	0.39	5.26	0.59	1.69	−0.21	−3.05	6.5	6.56	6.60	6.61	0.27	6.60	6.61	6.63	0.34
40.5	21.5	6.58	0.45	0.90	0.30	5.86	0.56	1.41	−0.15	−3.25	6.5	6.56	6.57	6.57	0.25	6.56	6.57	6.57	0.28
40.5	22.0	7.23	1.68	0.49	1.00	4.51	0.48	4.11	−0.47	−2.13	6.8	6.65	6.82	6.94	0.26	6.96	7.04	7.09	0.60
40.5	22.5	6.85	−4.78	0.98	0.32	12.55	0.55	3.29	−0.16	−6.77	6.8	6.84	6.85	6.85	0.29	6.82	6.84	6.84	0.30
40.5	23.0	7.26	−0.69	0.71	0.49	6.33	0.44	2.69	−0.20	−2.71	7.1	7.06	7.14	7.19	0.28	7.16	7.20	7.22	0.41
40.5	23.5	7.81	1.00	0.54	0.73	3.65	0.33	2.36	−0.23	−1.19	7.4	7.26	7.43	7.55	0.25	7.56	7.64	7.69	0.50
40.5	24.0	7.62	−2.64	0.72	0.51	7.50	0.38	3.32	−0.18	−2.84	7.4	7.38	7.48	7.53	0.29	7.50	7.55	7.58	0.42
40.5	24.5	7.53	−13.70	0.95	0.45	30.05	0.59	11.56	−0.24	−17.53	7.4	7.50	7.51	7.52	0.35	7.47	7.50	7.51	0.41
40.5	27.0	8.19	−0.17	0.46	1.25	4.97	0.35	5.72	−0.42	−1.70	7.4	7.14	7.42	7.63	0.28	7.69	7.83	7.93	0.69
40.5	27.5	7.96	−2.45	0.59	0.83	8.12	0.39	6.13	−0.32	−3.16	7.4	7.36	7.56	7.70	0.28	7.69	7.78	7.84	0.57

Table I. Continued

Lat.	Long.	ω	μ	λ	σ_ω	σ_μ	σ_λ	$\sigma_{\omega\mu}$	$\sigma_{\omega\lambda}$	$\sigma_{\mu\lambda}$	$\mathbf{M_{max}}$	$\mathbf{M_{50}}$	$\mathbf{M_{100}}$	$\mathbf{M_{200}}$	$\sigma_{\mathbf{M}}$	$\mathbf{M_{p50}}$	$\mathbf{M_{p100}}$	$\mathbf{M_{p200}}$	$\sigma_{\mathbf{Mp}}$
40.5	28.0	7.89	−3.21	0.63	0.75	9.04	0.40	6.09	−0.29	−3.60	7.4	7.40	7.57	7.68	0.28	7.67	7.75	7.80	0.54
40.5	28.5	7.71	−1.02	0.57	0.88	6.89	0.42	5.48	−0.35	−2.84	7.4	7.12	7.31	7.44	0.27	7.44	7.53	7.59	0.59
40.5	29.0	9.63	0.84	0.28	4.06	4.84	0.38	18.84	−1.54	−1.83	7.8	6.96	7.43	7.82	0.30	8.07	8.35	8.58	1.14
40.5	29.5	10.93	0.95	0.21	9.03	5.10	0.42	44.95	−3.79	−2.13	7.8	6.64	7.21	7.70	0.20	8.09	8.46	8.78	1.49
41.0	19.0	7.35	2.57	0.42	1.20	3.20	0.45	3.53	−0.52	−1.40	7.0	6.63	6.81	6.95	0.24	7.00	7.09	7.15	0.63
41.0	19.5	7.59	3.93	0.30	1.70	1.42	0.37	2.20	−0.61	−0.50	7.0	6.58	6.77	6.93	0.24	7.02	7.13	7.22	0.65
41.0	20.0	8.02	4.70	0.21	3.07	1.06	0.39	2.98	−1.19	−0.40	7.0	6.65	6.84	7.01	0.28	7.13	7.25	7.36	0.76
41.0	20.5	6.51	2.57	0.78	0.40	6.33	0.89	2.10	−0.33	−5.55	6.4	6.45	6.48	6.49	0.27	6.48	6.49	6.50	0.35
41.0	21.0	6.58	−0.73	0.95	0.32	10.48	0.75	2.73	−0.21	−7.77	6.5	6.57	6.58	6.58	0.28	6.56	6.57	6.57	0.30
41.0	22.0	7.75	0.55	0.47	1.18	5.16	0.41	5.61	−0.47	−2.10	7.1	6.91	7.14	7.31	0.26	7.36	7.47	7.55	0.67
41.0	22.5	8.93	1.56	0.32	2.06	2.71	0.28	5.22	−0.57	−0.74	7.8	7.10	7.47	7.76	0.25	7.93	8.13	8.29	0.78
41.0	23.0	8.03	−1.06	0.58	0.75	5.71	0.35	3.85	−0.25	−1.95	7.8	7.47	7.65	7.78	0.27	7.78	7.86	7.92	0.53
41.0	23.5	8.15	−4.14	0.68	0.59	7.40	0.31	3.81	−0.17	−2.29	7.8	7.75	7.90	7.99	0.29	7.96	8.03	8.08	0.46
41.0	24.0	8.27	−2.24	0.59	0.73	5.89	0.31	3.83	−0.21	−1.78	7.8	7.66	7.87	8.00	0.27	8.00	8.09	8.15	0.52
41.0	24.5	7.77	−8.66	0.74	0.68	17.68	0.47	10.73	−0.30	−8.23	7.4	7.45	7.58	7.66	0.32	7.60	7.67	7.71	0.54
41.0	25.5	7.72	3.60	0.21	8.34	5.00	0.99	40.64	−8.22	−4.89	6.6	6.00	6.24	6.44	0.00	6.60	6.75	6.88	1.40
41.0	26.0	8.71	3.08	0.19	11.08	4.84	0.76	52.37	−8.44	−3.65	6.9	6.08	6.40	6.68	0.63	6.91	7.13	7.32	1.64
41.0	26.5	9.97	2.67	0.17	11.25	3.56	0.50	38.96	−5.56	−1.74	7.3	6.30	6.70	7.06	0.00	7.38	7.66	7.92	1.17
41.0	27.0	8.46	1.64	0.35	1.67	2.69	0.29	4.16	−0.47	−0.76	7.4	6.99	7.31	7.56	0.26	7.69	7.85	7.99	0.72
41.0	27.5	7.96	−2.45	0.59	0.83	8.12	0.39	6.13	−0.32	−3.16	7.4	7.36	7.56	7.70	0.28	7.69	7.78	7.84	0.57
41.0	28.0	7.96	−2.45	0.59	0.83	8.12	0.39	6.13	−0.32	−3.16	7.4	7.36	7.56	7.70	0.28	7.69	7.78	7.84	0.57
41.0	28.5	7.74	−0.77	0.55	0.93	6.54	0.41	5.54	−0.37	−2.66	7.4	7.09	7.30	7.44	0.27	7.45	7.54	7.60	0.60
41.0	29.0	9.65	−1.31	0.33	3.61	7.09	0.39	24.70	−1.40	−2.73	7.8	6.96	7.50	7.94	0.15	8.18	8.48	8.71	1.15
41.5	19.0	7.78	2.68	0.33	2.21	3.52	0.48	7.30	−1.05	−1.67	7.0	6.58	6.83	7.03	0.28	7.13	7.27	7.37	0.86

Table I. Continued

Lat.	Long.	ω	μ	λ	σ_ω	σ_μ	σ_λ	$\sigma_{\omega\mu}$	$\sigma_{\omega\lambda}$	$\sigma_{\mu\lambda}$	$\mathbf{M_{max}}$	$\mathbf{M_{50}}$	$\mathbf{M_{100}}$	$\mathbf{M_{200}}$	$\sigma_\mathbf{M}$	$\mathbf{M_{p50}}$	$\mathbf{M_{p100}}$	$\mathbf{M_{p200}}$	$\sigma_\mathbf{Mp}$
41.5	19.5	7.74	3.33	0.32	2.01	2.40	0.43	4.48	−0.85	−1.00	7.0	6.60	6.82	7.00	0.25	7.11	7.23	7.33	0.75
41.5	20.0	8.04	4.18	0.24	2.38	1.12	0.33	2.46	−0.77	−0.35	7.0	6.65	6.87	7.05	0.22	7.18	7.32	7.43	0.69
41.5	20.5	6.88	4.27	0.43	0.78	1.38	0.45	0.94	−0.34	−0.60	6.6	6.50	6.60	6.67	0.23	6.70	6.74	6.78	0.47
41.5	21.0	6.51	1.00	0.86	0.37	8.47	0.81	2.58	−0.27	−6.79	6.4	6.47	6.49	6.50	0.28	6.48	6.49	6.50	0.33
41.5	21.5	6.53	1.76	0.75	0.52	9.60	1.00	4.28	−0.48	−9.45	6.4	6.44	6.47	6.50	0.29	6.48	6.50	6.51	0.43
41.5	22.0	7.76	2.35	0.38	1.88	4.53	0.52	8.00	−0.97	−2.34	7.1	6.73	6.97	7.15	0.24	7.23	7.35	7.45	0.81
41.5	22.5	9.01	−0.35	0.37	2.41	6.09	0.39	13.94	−0.92	−2.31	7.8	7.13	7.55	7.88	0.26	8.03	8.25	8.42	0.95
41.5	23.0	8.74	−1.22	0.42	1.86	7.03	0.39	12.37	−0.71	−2.70	7.8	7.21	7.59	7.88	0.21	7.99	8.18	8.32	0.86
41.5	23.5	8.13	−8.86	0.68	0.90	18.65	0.47	15.45	−0.41	−8.71	7.8	7.57	7.78	7.91	0.31	7.87	7.96	8.03	0.65
41.5	24.0	8.26	−4.34	0.55	1.26	12.72	0.47	15.02	−0.57	−5.89	7.8	7.33	7.63	7.83	0.27	7.84	7.98	8.07	0.76
41.5	27.0	7.92	−3.39	0.58	1.04	10.86	0.46	10.48	−0.46	−4.92	7.3	7.20	7.44	7.60	0.26	7.60	7.70	7.77	0.67
42.0	19.0	8.08	1.85	0.32	3.20	5.27	0.55	16.19	−1.74	−2.86	7.0	6.48	6.80	7.05	0.26	7.20	7.37	7.51	1.05
42.0	19.5	7.74	2.66	0.35	1.93	3.37	0.46	6.07	−0.87	−1.51	7.0	6.62	6.86	7.05	0.23	7.15	7.27	7.37	0.78
42.0	20.0	7.74	2.66	0.35	1.93	3.37	0.46	6.07	−0.87	−1.51	7.0	6.62	6.86	7.05	0.23	7.15	7.27	7.37	0.78
42.0	20.5	7.41	4.63	0.23	3.37	1.65	0.61	5.19	−2.04	−0.97	6.6	6.34	6.50	6.63	0.07	6.73	6.83	6.92	0.79
42.0	21.0	6.37	−0.05	0.87	0.50	21.79	1.47	9.35	−0.67	−31.75	6.3	6.34	6.35	6.36	0.34	6.34	6.35	6.36	0.43
42.0	21.5	6.29	−0.32	0.92	0.50	32.32	1.98	13.92	−0.90	−63.62	6.2	6.27	6.28	6.28	0.35	6.27	6.28	6.28	0.44
42.0	22.0	7.50	−1.20	0.57	1.13	12.04	0.65	12.56	−0.71	−7.75	7.1	6.94	7.12	7.25	0.30	7.25	7.33	7.39	0.73

4. Application

In order to give a detailed description of zone-free seismic activity, a $2° \times 2°$ degree cell with half degree overlap is used to scan smoothly throughout the region. The minimum extreme sample dataset was never less than six to ensure stability when the minimum "chi-square" was found (Equation (7)). Analysis of the 67 shallow seismic zones of course did not include a $2° \times 2°$ cell scan but was predetermined by the zone geometry and shape (Papazachos and Papazachou, 1997; Papaioannou and Papazachos, 2000), otherwise analysis procedures were identical to the zone-free procedure and results obtained where data sufficiency permitted it.

The zone-free maximum magnitudes expected over the next 50, 100 and 200 years are calculated on the basis of relation (11) and displayed in Figure 4. Earthquake magnitudes with 90% probability of being a maximum or not being exceeded over the same time periods are also estimated, using equation (12), see Figure 5. Full corresponding numerical results are listed in Table I.

On the basis of Equation (8), earthquake perceptibility is also calculated in respect to different intensity levels (I = VI, VII and VIII). Then the magnitude of the most perceptible earthquake corresponding to the highest probability (illustrated in Figure 3) is contoured throughout the study region (Figure 6).

5. Discussion and Conclusion

The extreme model should only be used under the assumption that the sampling interval is taken in a way so that the occurrence of an extreme magnitude earthquake is a random independent event and that the distribution of the extremes will repeat itself in the future (Yegulalp and Kuo, 1974). Based on the fitting theory alone, sufficient observational data are needed to produce a reliable and stable result if the solution exists, that is to ensure the fitting converges. So far as the present fitting is concerned, the number of extreme values can be increased by cutting shorter the time span interval (such as a half year or a few months) at the risk of introducing more foreshocks or aftershocks (non-independent observation). However, when the sample time interval is increased, the actual number of extreme observations must decrease, which also biases the fitting result. Furthermore, when extreme magnitudes are selected from increasingly longer time windows they inevitably tend towards higher values, so the magnitude range for the fitting will become narrower. The narrow magnitude span can lead to an increase of multi-values at one position (tied values) based on the plotting position relation (4), which can also lower the fitting quality. Therefore, selection of the sample interval plays an important role in determining the fitting precision. In the present paper, we calculated the parameters by choosing the minimum fitting error from a range of sample intervals.

The parameter ω provides a statistical bound to the largest size of the earthquakes for each seismic cell or zone. Most of the values are reasonable and acceptable except for the few cases with comparatively high values. These high values with large uncertainties, corresponding to little curvature, i.e., low λ, im-

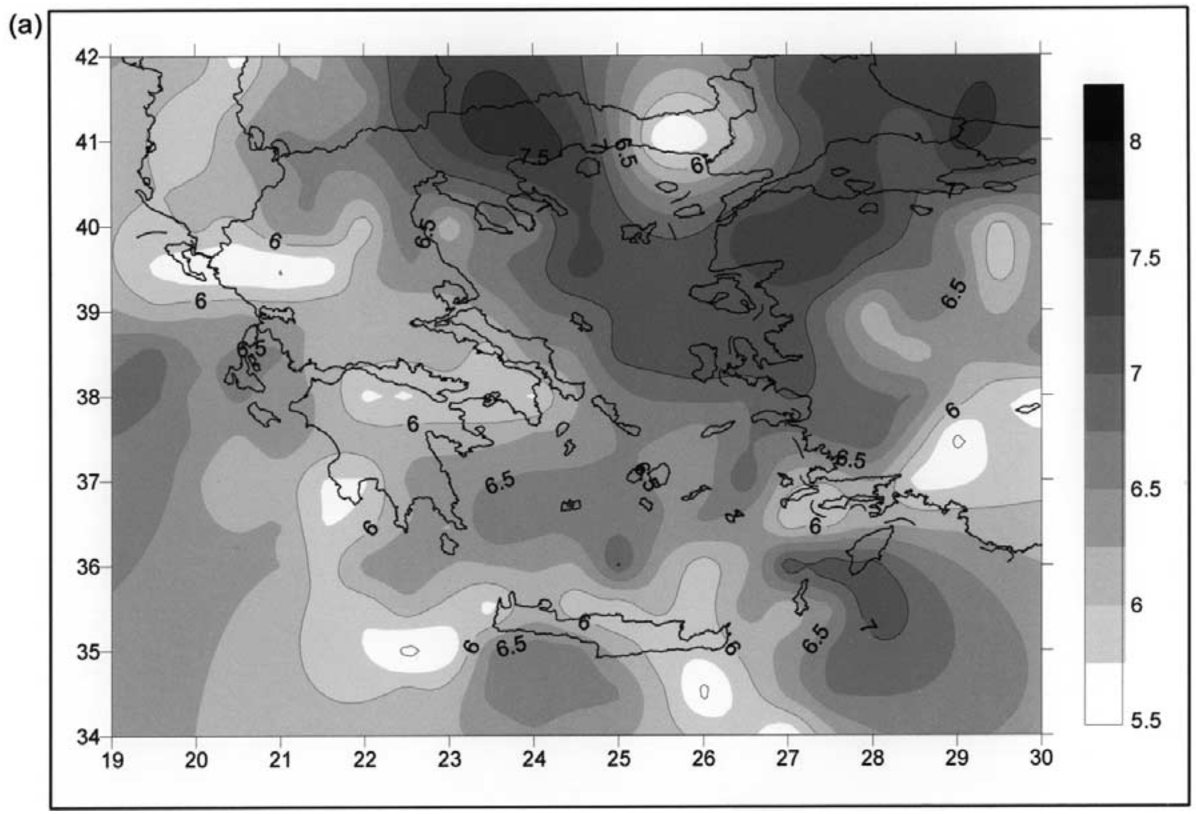

Figure 6. The most perceptible earthquake magnitude corresponding to the peak of the perceptibility curves for intensities VI (a), VII (b) and VIII (c) respectively (also see Figure 3 and Equation (8)).

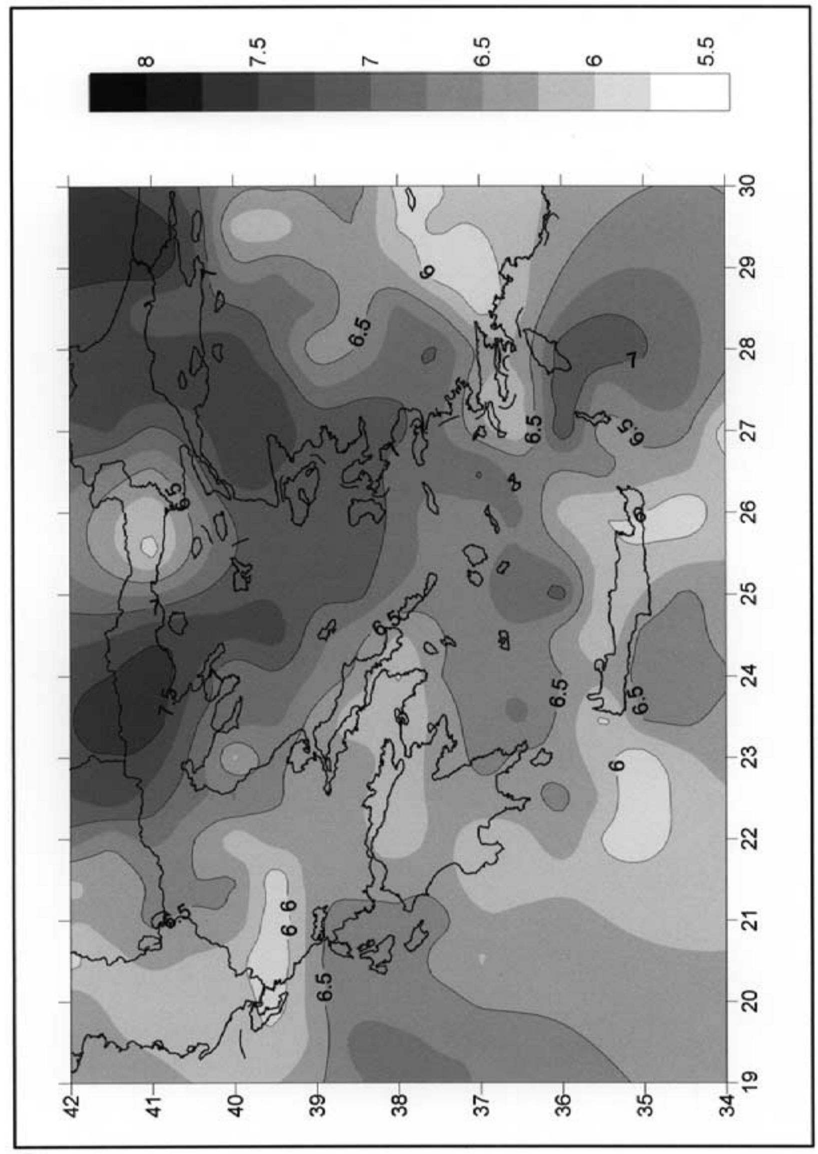

Figure 6. Continued.

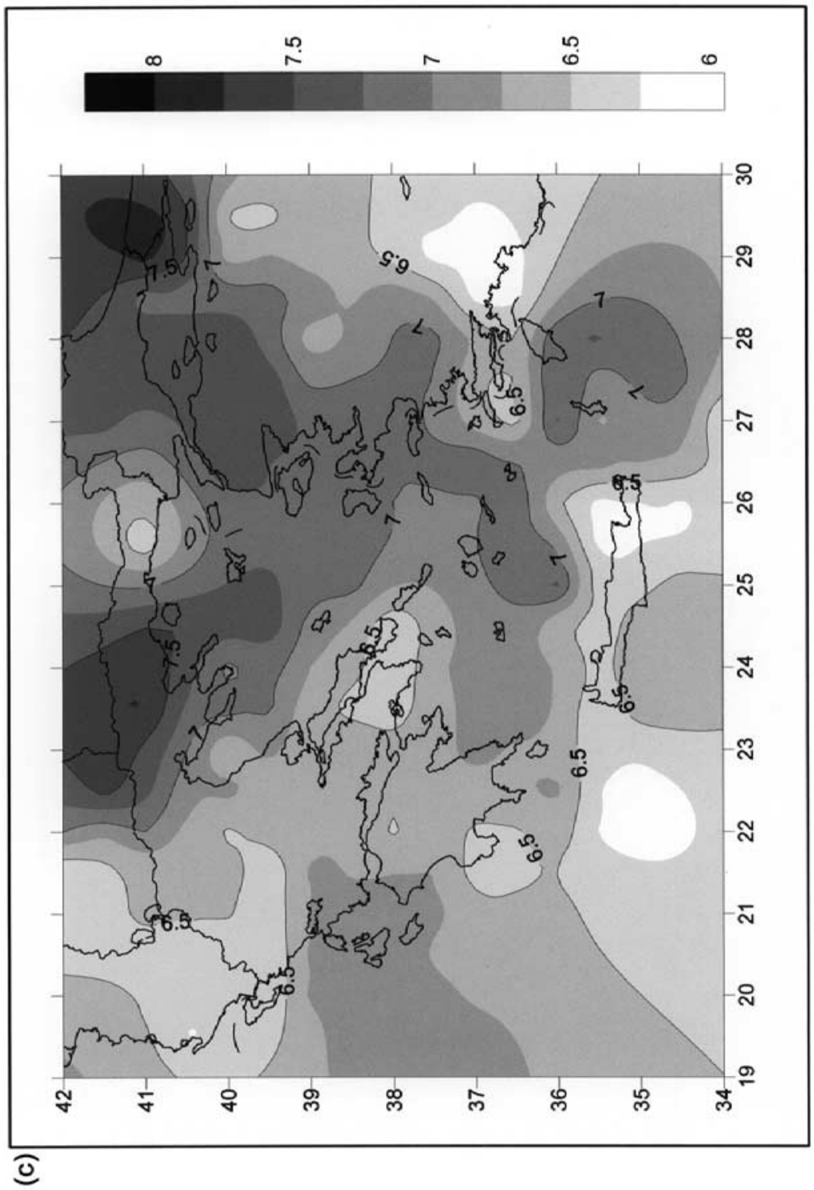

Figure 6. Continued.

ply that the upper value limits should not be regarded as reliable estimates of the upper bounds to magnitude. They are simply the best statistical fit to the present data (Burton, 1979, 1990). Yegulalp and Kuo (1974) thought an upper limit larger than 9.17, a so-called global upper limit, was simply indicative of deficiency in the data. It is anticipated that with an increase of independent observations, these high values will decrease to a reasonable magnitude. Small upper limit values, however, can simply imply the cell or zone either has low seismogenic potential or an insufficiency of observations.

The largest magnitudes expected over the next 50, 100 and 200 years are estimated using Equation (11) and zone-free cell results shown contoured throughout the study area in Figure 4. The earthquake magnitudes with 90% probability of not being exceeded (p.n.b.e.) over the next 50, 100 and 200 years are also calculated, mapped and contoured, illustrated in Figure 5. This sequence of maps brings out regional differences in seismicity and emphasizes differences in regional potential for large magnitude strong earthquake. The 50-year map (Figure 4a) immediately indicates well-known zones of large earthquake potential associated with: the Cephallonia Transform Fault of western Greece, a zone northeast of Thessaloniki near the Bulgarian border, high potential near south Rhodes, and extensive zones in northwest Turkey. When the time interval is incremented through to the next 100- and 200-years in Figures 4b–c, the regions of large earthquake potential tend to expand, for example, the high potential near Istanbul and association with the trend of the North Anatolian Fault becomes clearer in Figure 4c, and the area in north Greece near the Bulgarian border becomes more dominant. Progression through the sequence of maps for 50-, 100- and 200-years at the 90% p.n.b.e. level in Figures 5a–c develops further trends in earthquake potential as high seismicity characteristics of regions move at a decreasing rate (the hazard curves do not progress in equal increments but are curved through the shape parameter λ) towards their regional upper-bound magnitude specified statistically as the parameter ω: for instance, high earthquake potential becomes even more closely associated with the Corinth Gulf and central Greece, and the zone in north Greece now emerges as two adjacent regions prone to large earthquake straddling the Bulgarian-Greek-Macedonian borders. This latter observation is entirely compatible with the p.g.a. seismic hazard analysed separately (Burton *et al.*, 2003).

These forecasts or "predictions" are compatible with the general spatial distribution of seismicity (Figure 1) and with the ones estimated individually for the seismic activity within the 67 seismic zones outlined by Papazachos and his colleagues (zones defined in Figure 7 insets). Analysis of all 67 zones was not rewarded by a full list of parameters, largely because some zones are relatively small, lack data, and proved intractable. Figure 7a illustrates the 50-year 90% p.n.b.e. earthquake magnitude for 17 zones (also see Table IIa). These calculations were made using a completeness magnitude of $5.5M$, as standard in this paper. Relaxing this threshold to $5.0M$, and the data indicate that this is a reasonable step whereas $4.5M$ would not be, produces similar results for a further 32 zones, 49 zones in all (Figure 7b and Table IIb). Comparing the 50-year 90% p.n.b.e. value of M ($\mathbf{M_{p50}}$ in the tables) for the 17 zones producing results with either threshold reveals: an average shift in $\mathbf{M_{p50}}$ of -0.02, i.e., $\rightarrow$ 0.0 and a range of shifts spanning ± 0.30, indeed over 50% show no change in $\mathbf{M_{p50}}$. The pattern and level of forecasts illustrated in Figures 5a and 7b are, like the comparison with seismicity in Figure 1, also compatible.

The most perceptible magnitude can be used as an earthquake selection criterion for anti-seismic design of noncritical structures (Burton, 1990) because it describes theoretically the earthquake which is most likely to cause a particular level of damage and destruction (intensity). On the basis of (8), the earthquake perceptibility curves at the different intensity levels VI, VII and VIII were obtained as a function of magnitude as illustrated generally in Figure 3. The magnitude of the most perceptible earthquake identifies that earthquake with highest probability of causing damage at a specific intensity level in a cell or zone – this magnitude, the most perceptible magnitude, corresponds to the peak of the probability curve in schematic Figure 3c. The most perceptible magnitude is determined cell-by-cell at the three separate intensity levels VI, VII and VIII, and the contoured results produce Figures 6a–c respectively. First note that perceptibility is deliberately calculated at intensities VI, VII and VIII MSK (EMS) because VI is the threshold of damage and VII is the threshold of damage to reinforced concrete structures (VIII represents the onset of more serious damage). Note also that there is a low-magnitude threshold or cutoff in the function $P_c(I)$, hence also in perceptibility $P_c(I \mid M)$, as illustrated in Figure 3. The cutoff magnitudes, based on the attenuation relation (9) are 4.57 M, 5.27 M and 5.97 M for intensity VI, VII and VIII respectively. This is reasonable because it cannot be expected that a low-magnitude event can normally cause high levels of ground motion and, secondly, because of the form of (9). The perceptibility curves at higher intensities are systematically shifted towards larger events and the most perceptible magnitude realistically follows this trend. It should also be noted that there is a high-magnitude cutoff in perceptibility $P_c(I \mid M)$ because the form of the function $P_e(M)$ describing seismicity has an upper limit to magnitude (in this case the parameter ω). The shape of the perceptibility curve with its “most perceptible earthquake” where maximum probability of perception exists, emphasizes the fact that it is these earthquakes, rather than the considerably rarer ones close to a conceptual maximum magnitude of diminishing probability, which are more likely to cause substantial damage.

In the case of a seismic hazard analysis directed at scenario earthquake selection for the city of Potenza, Italy final results included: magnitude of the most perceptible earthquake at intensity VII was about 7.0 M; maximum credible earthquake from strain energy analysis was within 7.0-7.5 M with waiting time within circa 72–118 years; the statistical upper bound ω was $\sim$7.7 M (Burton, 2003). Potenza is effectively equivalent to one cell, albeit in detail, of the current analysis – contoured Figures 4, 5 and perceptibility Figure 6 condense and simplify an enormous amount of seismicity and hazard information. For instance, in Cephallonia in the west

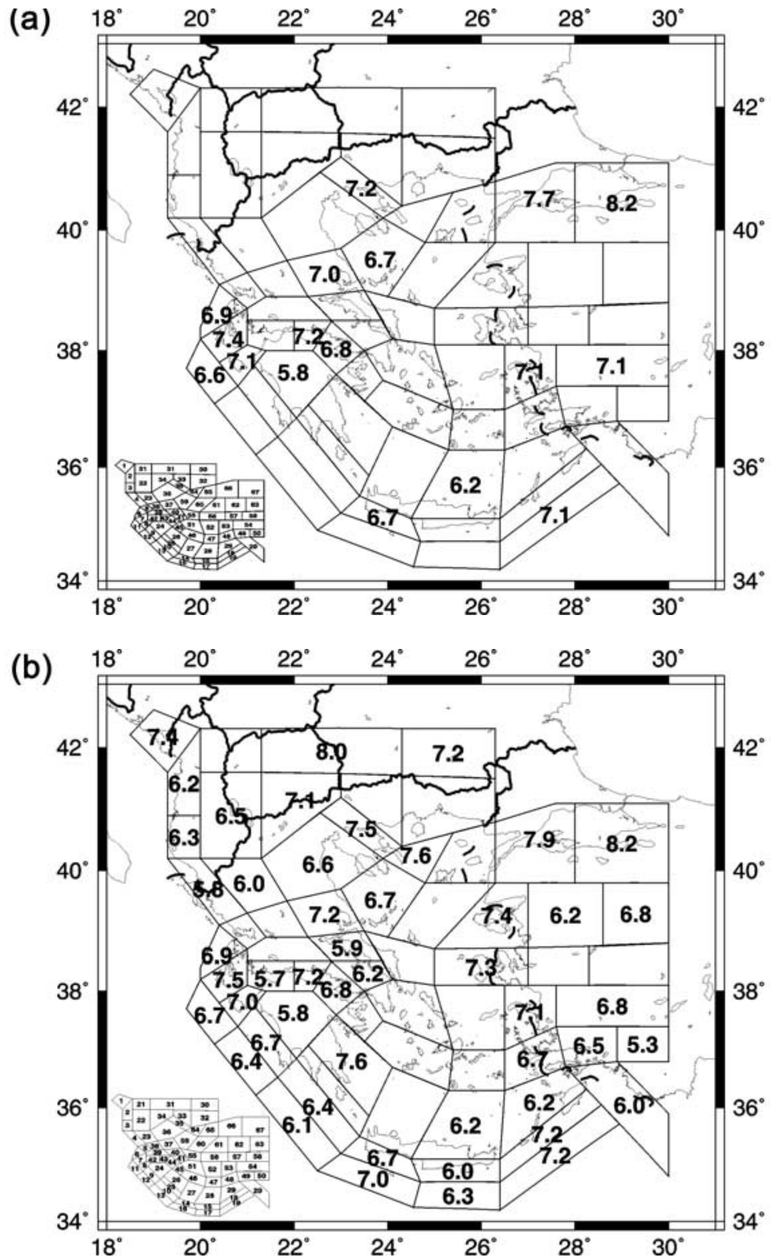

Figure 7. Zoned analysis. The magnitude expected with a non-exceedance probability of 90% (1 in 10 chance of exceedance) over a time period of 50-years estimated for the 67 zones outlined by Papazachos and his colleagues. (a) results for 17 zones (obtained using a magnitude threshold of $5.5M$ as standard in this paper, (b) results for 49 zones (using a magnitude threshold of $5.0M$). There are insufficient data to obtain results for all zones.

Table IIa. Zoned analysis. Results (catalogue 1900–1999, $M \geq 5.5$) for the Papazachos and colleagues' zones shown in Figure 7a. ω, σ_ω, σ_μ, λ, σ_λ are the three parameters of the Gumbel III model and the corresponding errors and $\sigma_{\omega\mu}$, $\sigma_{\omega\lambda}$ and $\sigma_{\mu\lambda}$ are the corresponding covariances of the parameters. $\mathbf{M_{max}}$ is the maximum earthquake observed in each zone. $\mathbf{M_{50}}$, $\mathbf{M_{100}}$, $\mathbf{M_{200}}$, and $\mathbf{M_{p50}}$, $\mathbf{M_{p100}}$, $\mathbf{M_{p200}}$ are the maximum magnitude and the magnitude with 90% probability of being a maximum (1 in 10 chance of being exceeded) in the next 50, 100 and 200-years respectively. $\sigma_{\mathbf{M}}$ and $\sigma_{\mathbf{Mp}}$ are the uncertainties on these magnitude forecasts.

Lat.	Long.	ω	μ	λ	σ_ω	σ_μ	σ_λ	$\sigma_{\omega\mu}$	$\sigma_{\omega\lambda}$	$\sigma_{\mu\lambda}$	$\mathbf{M_{max}}$	$\mathbf{M_{50}}$	$\mathbf{M_{100}}$	$\mathbf{M_{200}}$	$\sigma_{\mathbf{M}}$	$\mathbf{M_{p50}}$	$\mathbf{M_{p100}}$	$\mathbf{M_{p200}}$	$\sigma_{\mathbf{Mp}}$
38.60	20.35	7.38	2.33	0.39	1.92	5.30	0.63	9.58	−1.19	−3.30	6.7	6.48	6.69	6.86	0.29	6.93	7.03	7.12	0.68
38.20	20.60	7.70	−2.92	0.60	0.83	8.89	0.41	6.71	−0.33	−3.64	7.3	7.12	7.32	7.45	0.20	7.44	7.53	7.59	0.49
37.82	20.90	7.60	1.28	0.41	1.70	5.04	0.48	8.02	−0.80	−2.38	6.9	6.55	6.81	7.00	0.24	7.08	7.21	7.30	0.64
37.60	20.20	6.68	−10.87	0.95	0.53	45.18	0.99	20.94	−0.48	−44.67	6.5	6.66	6.67	6.67	0.28	6.63	6.65	6.67	0.43
35.13	23.90	6.96	1.75	0.49	1.21	6.75	0.70	7.58	−0.82	−4.64	6.5	6.42	6.58	6.69	0.21	6.71	6.78	6.83	0.57
35.17	27.58	8.42	1.79	0.26	5.65	5.91	0.62	32.43	−3.50	−3.63	6.9	6.20	6.57	6.87	0.21	7.08	7.30	7.49	0.91
37.64	21.98	5.86	2.92	0.75	0.71	20.09	2.93	12.83	−1.96	−58.29	5.8	5.80	5.83	5.84	0.22	5.83	5.84	5.85	0.49
35.70	25.67	6.22	−3.08	0.90	0.57	38.98	1.64	19.69	−0.87	−63.51	6.1	6.19	6.20	6.21	0.25	6.18	6.20	6.21	0.45
40.69	23.44	7.33	−14.99	0.86	0.62	34.39	0.61	18.80	−0.35	−20.82	7.1	7.19	7.25	7.29	0.23	7.22	7.27	7.30	0.46
39.28	22.66	7.02	−12.64	0.94	0.48	31.61	0.66	12.97	−0.29	−20.71	6.8	6.98	7.00	7.01	0.27	6.96	6.99	7.00	0.39
38.25	22.30	7.70	0.57	0.45	1.46	5.93	0.47	8.07	−0.67	−2.74	7.2	6.75	7.00	7.19	0.23	7.25	7.37	7.46	0.62
38.03	22.90	6.94	−4.65	0.70	0.87	20.74	0.75	16.61	−0.63	−15.51	6.6	6.61	6.74	6.81	0.22	6.78	6.84	6.88	0.55
37.65	27.05	7.81	2.22	0.33	2.64	4.52	0.54	11.33	−1.40	−2.39	7.0	6.47	6.74	6.96	0.20	7.08	7.23	7.35	0.72
37.75	28.80	8.94	2.56	0.20	9.47	5.04	0.66	46.53	−6.24	−3.29	7.0	6.16	6.52	6.84	0.46	7.09	7.33	7.54	1.11
39.52	23.84	6.85	−1.92	0.71	0.84	21.77	1.04	16.72	−0.83	−22.41	6.6	6.63	6.71	6.77	0.24	6.74	6.78	6.81	0.54
40.52	27.24	7.97	−3.04	0.58	0.91	8.55	0.39	7.14	−0.34	−3.29	7.4	7.28	7.51	7.66	0.20	7.66	7.76	7.83	0.52
40.45	29.00	9.65	−1.31	0.33	3.61	7.09	0.39	24.70	−1.40	−2.73	7.8	6.96	7.50	7.94	0.35	8.18	8.48	8.71	0.85

Table IIb. Zoned analysis. Results (catalogue 1900–1999, $M \geq 5.0$) for the Papazachos and colleagues' zones shown in Figure 7b. Analysis and notation is identical to Table IIa except for the lower magnitude threshold used of 5.0 M in each zone.

Lat.	Long.	ω	μ	λ	σ_ω	σ_μ	σ_λ	$\sigma_{\omega\mu}$	$\sigma_{\omega\lambda}$	$\sigma_{\mu\lambda}$	$\mathbf{M_{max}}$	$\mathbf{M_{50}}$	$\mathbf{M_{100}}$	$\mathbf{M_{200}}$	$\sigma_\mathbf{M}$	$\mathbf{M_{p50}}$	$\mathbf{M_{p100}}$	$\mathbf{M_{p200}}$	$\sigma_\mathbf{Mp}$
42.17	19.20	8.57	−1.25	0.35	2.70	5.71	0.36	14.71	−0.95	−2.02	7.0	6.38	6.85	7.21	0.28	7.41	7.65	7.85	1.00
41.42	19.65	6.42	3.10	0.43	1.09	2.79	0.58	2.77	−0.61	−1.58	6.1	5.93	6.06	6.15	0.26	6.18	6.24	6.29	0.60
40.55	19.65	6.58	2.11	0.45	1.10	3.60	0.51	3.60	−0.55	−1.81	6.1	5.99	6.15	6.26	0.25	6.30	6.37	6.43	0.61
39.70	20.17	6.31	4.64	0.18	6.75	2.27	1.46	14.60	−9.81	−3.23	5.7	5.53	5.62	5.71	0.29	5.78	5.84	5.90	1.12
38.60	20.35	7.53	3.36	0.30	1.48	1.02	0.26	1.36	−0.38	−0.25	6.7	6.36	6.58	6.76	0.21	6.87	6.99	7.09	0.58
38.20	20.60	9.44	3.15	0.19	3.23	0.76	0.18	2.25	−0.57	−0.13	7.3	6.60	6.96	7.27	0.23	7.53	7.76	7.97	0.71
37.82	20.90	7.97	2.97	0.27	2.19	1.49	0.29	3.01	−0.62	−0.42	6.9	6.39	6.66	6.88	0.20	7.03	7.20	7.33	0.71
37.13	21.41	7.96	3.26	0.21	3.81	1.46	0.35	5.21	−1.31	−0.49	6.7	5.99	6.26	6.49	0.22	6.67	6.85	7.00	0.83
36.02	22.52	6.64	−1.04	0.58	0.90	8.65	0.56	7.13	−0.49	−4.82	6.2	6.17	6.33	6.43	0.28	6.43	6.50	6.55	0.61
37.60	20.20	7.08	2.53	0.40	1.02	1.78	0.31	1.62	−0.31	−0.54	6.5	6.31	6.50	6.64	0.25	6.70	6.79	6.86	0.55
36.81	20.98	7.51	1.85	0.27	5.35	6.03	0.73	31.30	−3.89	−4.35	6.1	5.68	5.99	6.24	0.16	6.42	6.60	6.76	1.29
35.71	22.08	6.24	−0.59	0.65	0.83	12.74	0.86	9.63	−0.68	−10.85	6.0	5.97	6.07	6.13	0.30	6.12	6.16	6.19	0.60
35.13	23.90	6.98	2.44	0.44	0.79	1.56	0.28	1.08	−0.21	−0.42	6.5	6.35	6.52	6.64	0.24	6.68	6.76	6.82	0.48
34.90	25.50	6.82	4.08	0.20	3.77	1.16	0.52	4.07	−1.96	−0.58	6.1	5.62	5.77	5.91	0.27	6.02	6.12	6.21	0.81
34.76	23.69	8.28	2.52	0.25	3.29	2.07	0.33	6.43	−1.08	−0.67	6.6	6.23	6.55	6.82	0.31	7.02	7.21	7.38	0.89
34.46	25.51	7.31	4.04	0.19	4.11	1.15	0.45	4.33	−1.84	−0.49	6.3	5.83	6.01	6.18	0.20	6.31	6.43	6.54	0.81
35.54	27.41	9.76	2.89	0.16	6.54	1.30	0.26	8.03	−1.69	−0.33	7.2	6.17	6.55	6.88	0.36	7.18	7.45	7.69	0.97
35.17	27.58	8.40	0.95	0.29	3.46	4.24	0.41	13.99	−1.39	−1.70	6.9	6.25	6.65	6.97	0.28	7.17	7.39	7.58	1.06
36.05	29.17	6.11	−1.55	0.75	0.56	12.41	0.76	6.08	−0.40	−9.34	5.9	5.97	6.03	6.06	0.30	6.04	6.07	6.08	0.46
40.90	20.65	6.51	−0.68	0.93	0.32	9.13	0.68	2.34	−0.19	−6.10	6.4	6.49	6.50	6.51	0.27	6.49	6.50	6.50	0.30
39.80	21.04	6.32	2.41	0.41	1.50	4.41	0.69	6.18	−1.02	−3.01	5.9	5.70	5.85	5.97	0.26	6.01	6.09	6.15	0.74
37.64	21.98	5.86	3.04	0.73	0.36	2.97	0.72	0.86	−0.24	−2.07	5.8	5.80	5.82	5.84	0.25	5.83	5.84	5.85	0.31
36.81	23.23	9.18	−1.44	0.31	4.08	6.72	0.40	26.47	−1.60	−2.63	7.0	6.32	6.87	7.31	0.39	7.58	7.89	8.13	1.26
35.70	25.67	6.33	2.28	0.53	0.77	3.58	0.56	2.44	−0.41	−1.94	6.1	5.98	6.09	6.16	0.26	6.17	6.22	6.25	0.51
36.11	27.24	6.26	−4.19	0.77	0.64	18.96	0.78	10.90	−0.47	−14.73	6.0	6.09	6.16	6.20	0.32	6.17	6.21	6.23	0.52

Table IIb. Continued.

Lat.	Long.	ω	μ	λ	σ_ω	σ_μ	σ_λ	$\sigma_{\omega\mu}$	$\sigma_{\omega\lambda}$	$\sigma_{\mu\lambda}$	$\mathbf{M_{max}}$	$\mathbf{M_{50}}$	$\mathbf{M_{100}}$	$\mathbf{M_{200}}$	$\sigma_\mathbf{M}$	$\mathbf{M_{p50}}$	$\mathbf{M_{p100}}$	$\mathbf{M_{p200}}$	$\sigma_\mathbf{Mp}$
41.91	25.30	11.80	2.20	0.12	19.53	2.53	0.37	47.96	−7.30	−0.93	7.1	5.84	6.31	6.74	0.00	7.16	7.52	7.86	1.25
41.94	22.80	10.97	1.76	0.19	5.24	1.56	0.20	7.76	−1.04	−0.30	7.8	6.69	7.20	7.66	0.37	8.04	8.40	8.71	0.95
41.15	22.15	8.54	−0.50	0.30	4.21	6.63	0.46	26.95	−1.94	−3.04	6.8	6.05	6.52	6.90	0.28	7.13	7.40	7.62	1.24
40.69	23.44	8.83	0.86	0.29	3.13	3.76	0.34	11.20	−1.06	−1.27	7.1	6.55	6.97	7.31	0.22	7.53	7.77	7.96	0.98
40.11	22.52	7.07	1.26	0.42	1.34	4.12	0.44	5.12	−0.58	−1.78	6.5	6.20	6.42	6.59	0.23	6.65	6.75	6.84	0.68
39.28	22.66	7.85	1.54	0.38	1.20	1.90	0.24	2.06	−0.28	−0.44	6.8	6.65	6.93	7.14	0.25	7.24	7.38	7.49	0.60
38.72	23.13	6.20	1.44	0.45	1.90	10.17	1.07	18.40	−2.01	−10.82	5.8	5.59	5.75	5.87	0.13	5.91	5.99	6.05	0.92
38.30	23.58	6.26	4.00	0.94	0.34	11.20	0.56	3.10	−0.17	−6.15	6.1	6.24	6.25	6.25	0.28	6.23	6.24	6.25	0.31
38.22	21.48	6.09	4.41	0.22	4.39	2.10	1.23	8.75	−5.36	−2.53	5.6	5.41	5.51	5.59	0.27	5.65	5.71	5.77	0.97
38.25	22.30	8.26	2.95	0.27	2.03	1.18	0.23	2.19	−0.47	−0.27	7.2	6.53	6.82	7.07	0.26	7.23	7.40	7.55	0.68
38.03	22.90	7.10	0.18	0.51	0.98	5.34	0.44	4.74	−0.41	−2.29	6.6	6.46	6.65	6.78	0.26	6.81	6.89	6.96	0.61
36.85	27.10	8.07	1.87	0.25	5.05	4.42	0.54	21.57	−2.70	−2.35	6.7	5.91	6.25	6.54	0.30	6.75	6.96	7.14	1.20
37.08	28.30	7.23	1.58	0.33	3.14	5.93	0.65	17.83	−2.03	−3.82	6.2	5.86	6.14	6.36	0.25	6.49	6.64	6.76	1.07
37.10	29.45	5.39	3.54	0.51	1.29	9.06	2.46	10.90	−3.08	−22.00	5.3	5.22	5.27	5.31	0.29	5.31	5.34	5.35	0.75
37.65	27.05	7.81	2.22	0.33	2.64	4.52	0.54	11.33	−1.40	−2.39	7.0	6.47	6.74	6.96	0.19	7.08	7.23	7.35	0.95
37.75	28.80	8.04	3.00	0.23	3.10	1.54	0.32	4.47	−0.97	−0.47	7.0	6.14	6.43	6.67	0.23	6.85	7.03	7.18	0.80
38.40	26.00	9.62	0.67	0.22	7.23	4.76	0.43	33.41	−3.06	−2.00	7.0	6.05	6.56	6.99	0.25	7.33	7.65	7.93	1.37
39.52	23.84	6.75	−1.73	0.79	0.42	6.67	0.44	2.29	−0.17	−2.87	6.6	6.63	6.68	6.71	0.28	6.68	6.71	6.73	0.36
39.26	26.33	8.32	2.14	0.31	1.67	1.64	0.23	2.51	−0.39	−0.37	7.0	6.72	7.03	7.29	0.25	7.43	7.61	7.75	0.67
39.27	27.80	6.26	−5.85	0.84	0.60	27.92	0.94	14.90	−0.53	−26.18	6.1	6.16	6.21	6.23	0.35	6.19	6.22	6.24	0.51
39.29	29.30	7.04	−4.47	0.66	0.95	18.81	0.70	16.45	−0.64	−13.06	6.7	6.62	6.78	6.87	0.31	6.85	6.92	6.96	0.67
40.26	24.60	7.75	−34.02	0.93	0.55	42.71	0.40	20.44	−0.20	−16.85	7.4	7.66	7.70	7.73	0.38	7.62	7.68	7.71	0.48
40.52	27.24	8.87	1.04	0.33	1.67	2.04	0.21	3.14	−0.35	−0.42	7.4	6.99	7.38	7.68	0.22	7.85	8.06	8.23	0.68
40.45	29.00	9.70	−1.67	0.33	2.90	5.56	0.31	15.40	−0.88	−1.68	7.8	7.00	7.56	8.00	0.24	8.24	8.54	8.78	1.01

intensities VI and VII are most likely to arise from a most perceptible earthquake around 6.5 M, but this rises near to 7.0 M for intensity VIII to be reached. This contrasts to the situation in north-east Greece, near the Bulgarian-Greek-Macedonian border, where the most perceptible earthquake has magnitude 7.5 M at intensity VI, VII and VIII, and the area affected thus characterized grows with increasing intensity level. In the Shields earthquake early warning study area near Athens and the eastern Corinth Gulf (Burton and Tselentis, 2002), the most perceptible earthquake has magnitude 6.5 M at intensity VIII inside the early warning shield near to Athens and 6.5–7.0 M further west in the Corinth Gulf – these are the earthquake magnitudes likely to cause "-“alert signals” of interest to the early warning system. Selection of reference earthquakes should depend on possible event consequences rather then extreme rarity of an isolated event and Goretti (2003) has extended the perceptibility concept to building collapse, economic loss and building usability (unusability corresponding to homelessness).

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