Unified Scaling Law for Earthquakes as Applied to Assessment of Seismic Hazard and Associate Risks

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Abstract—The distribution of the number of seismic events by magnitudes—the Gutenberg–Richter frequency–magnitude relation—is of paramount importance for seismic hazard assessment of a territory. The generalization of the Gutenberg–Richter relation—the Unified Scaling Law for Earthquakes (USLE) proposed in 1988 makes it possible to take into account the pattern of epicentral distribution of seismic events when changing the spatial scale of the analysis. This is extremely important for adequate downscaling of the frequency of occurrence into a smaller area within the territory under study (e.g., in the megalopolis). In 2002, Per Buck suggested a dual formulation of USLE where, instead of the number of earthquakes over a certain period of time, the reciprocal of their frequency of occurrence—the time between seismic events—is used. The same year, the Institute of Earthquake Prediction Theory and Mathematical Geophysics of the Russian Academy of Sciences developed a modified algorithm for robust estimation of USLE parameters referred to as Scaling Coefficients Estimation (SCE) for producing seismic hazard maps of territories prone to seismic effects. This brief review is focused on the use of the USLE approach to the assessment of seismic hazard and associated risk.

Keywords: seismic hazard, Unified Scaling Law for Earthquakes, population, peak ground acceleration, seismic risk

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INTRODUCTION

Seismic hazard assessment requires an adequate notion of the distribution of earthquakes having different magnitudes. Currently, in response to a search query for "unified scaling law for earthquakes," in a fractions of a second, a Google search engine yields millions of references to the works that are directly related to the studies of seismicity and that use a some form of the Unified Scaling Law for Earthquakes which generalizes one of the Gutenberg–Richter relations (Gutenberg and Richter, 1844; 1956). The Gutenberg–Richter law for the recurrence of earthquakes is typically formulated as a relation linking the annual average number $N(M)$ and magnitude M of earthquakes in a certain volume in space and time:

$$\log_{10} N(M) = a + b(5 - M), \quad M_- \leq M \leq M^-, \quad (1)$$

where coefficient a characterizes the average seismicity in the entire spatiotemporal volume of the study territory and b is the number ratio of earthquakes in the neighboring magnitude bins. The existing seismic hazard maps are reasonably consistent with the maps of seismicity index a. However, it should be noted that as a rule, these maps overestimate the earthquake hazards in the aseismic zones because of (1) the arbitrarily selected probability space (typically, Poisson in time and determined by Gaussian partition of unity in space) and (2) the underestimated effects of classical scaling which ignores the complex (fractal) structure of the areas prone to the emergence of earthquake epicenters. Perhaps a more accurate modification of the similarity law for earthquakes was suggested in 1988 in (Kossobokov and Mazhkenov, 1988; Keilis-Borok et al., 1989). This modification allows for scaling of the study territory and of the distribution of seismic epicenters over the area:

$$\log_{10} N(M, L) = A + B(5 - M) + C\log_{10} L. \quad (2)$$

The USLE formulation that uses a dual quantity—the time between seismic events—instead of the number of earthquakes in a certain period of time was suggested in 2002 (Bak et al., 2002; Christensen et al., 2002). This motivated the development of a modified algorithm for robust estimation of USLE parameters and their global mapping—the Scaling Coefficients Estimation (SCE) algorithm (Nekrasova and Kossobokov, 2002; Kossobokov and Nekrasova, 2004). The maps of the USLE coefficients obtained in the Institute of Earthquake Prediction Theory and Mathematical Geophysics RAS with the use of the Global Hypocenter Database of Earthquakes (GHDB, 2015) for 1964–2002 were included in the Report of the Russian Academy of Sciences on the main scientific achievements for 2002 (*Otchet* ..., 2003).

USLE yields the estimate of the expected maximum magnitude of the earthquakes at the sites of their occurrence which provides the possibility of calculating and mapping the expected parameters of ground shaking (for example, peak ground acceleration (PGA) or macroseismic intensity I_0) in the study region. After thorough testing based on seismic manifestations (for example, PGA or I_0 values recorded in the past), such a map can be used in practice to assess the estimating the specific risks of earthquake consequences for the population, cities and infrastructures (for example, based on census data, inventory of buildings and other units of infrastructure).

In the past years, the ULSE-based seismic hazard maps in terms of the recurrence time of seismic events with the maximum expected magnitude have been constructed for several regions of the world which differ both in the size of the territory of interest and in the level of seismic activity (Parvez et al., 2014; 2017; 2018; Kossobokov and Nekrasova, 2004; 2018a; 2018b; Nekrasova et al., 2011; 2015; 2016; Nekrasova and Kossobokov, 2003; 2005; 2006; 2009; 2016; 2015). In particular, in the territory of the Russian Federation, the maps based on the calculations of ULSE coefficients were constructed for the Baikal region, Altai, Sayan, the Greater Caucasus, and the Crimean peninsula. Seismic hazard maps were also built for the Hindustan Peninsula, Gujarat State (India), Gansu Province (China), and the Friuli-Venezia Giulia autonomous region of Italy.

Pilot calculations of model seismic risks for population were proposed for the listed territories and some largest cities therein. It is shown that disregarding the fractal nature of the spatial distribution of earthquakes can result in a significant underestimation of seismic hazard and associated risks and, hence, to the significant unanticipated losses and damage in case they occur.

APPLICATION OF USLE IN STUDYING THE SEISMICITY ON SPATIAL AND TIME SCALES

The modified version of the SCE algorithm for determining the USLE parameters is described in detail in (Nekrasova et al., 2015). We note that the free parameters of the algorithm impose certain limitations on its application possibilities and initial data. In particular, the correct application of the SCE algorithm requires a seismic catalog covering a long period (from ten years or more) of recording by a homogeneous, in terms of the technical parameters, network. Clearly, the calculation results depend on the initial data, specifically, on the completeness of event recording, the changes in earthquake detection threshold in the process of upgrading the instruments and improving the parameters of a seismograph network, the determination accuracy of epicentral coordinates, and, to a lesser extent, the depth of seismic events. The catalog used in a study largely determines the preliminary selection of the optimal set of free parameters of the algorithm. The analysis of catalog data is a mandatory step in applying the SCE algorithm. For example, the above global mapping of the USLE parameters was carried out with the use of the data on all seismic events with magnitudes starting from 4.0 from the catalog of the U.S. Geological Survey for 1964–2002 (Global Hypocentres Data Base). In that mapping, the USLE coefficients shown in Fig. 1 were estimated on the scale of the units of global plate tectonics with sizes ranging from 50 to 1000 km. A five-step spatial hierarchy of the cells with a linear size from 0.5 to 8 degrees of arc of the Earth's meridian was used. According to (Nekrasova and Kossobokov, 2002; Kossobokov and Nekrasova, 2004), the logarithmic estimate of seismicity (coefficient A) mainly varies from -2.5 to -1.2 (Fig. 2a) which corresponds to the frequency of occurrence of magnitude 5.0 earthquakes from less than one event per 300 years to three events per fifty years. The Gutenberg b-values (coefficient B) are mainly concentrated between 0.6 and 1.1 (Fig. 2b), and the fractal dimension of seismic locus at a given location (coefficient C) varies from below 1.0 to 1.4 and higher (Fig. 2c). Practically all over the world, the obtained uncertainty estimates of the USLE coefficients (Fig. 2d) are highly consistent with the world observation data in a wide range of magnitudes and sizes of a study area.

The estimates of the USLE parameters over a long time interval can be used for constructing seismic hazard maps for a study territory and will be discussed below. The medium-term change of the USLE parameters characterizes the dynamics of seismicity of the studied region. In particular, it was established (Bak et al., 2002; Kossobokov and Nekrasova, 2017; 2019) that on the long time scales, the USLE control parameter, namely, quantity $\eta = N^{-1} \times 10^{B \times (5 - M)} \times L^C$ is stuck to one of its rather stable levels; from time to time, it switches from one level to another as a result of
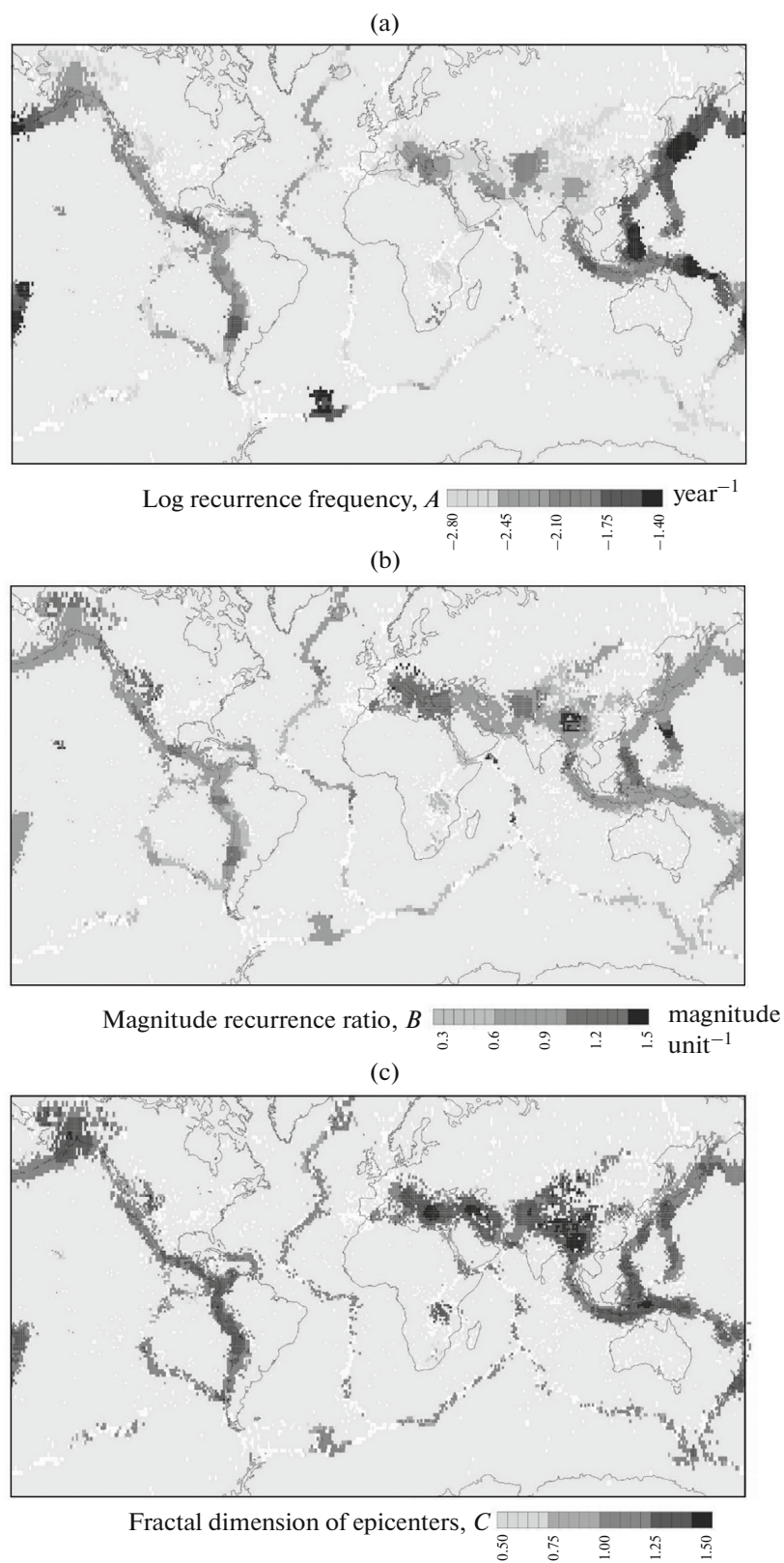
(a)

Log recurrence frequency, A year^{-1}

−2.80   −2.45   −2.10   −1.75   −1.40

(b)

Magnitude recurrence ratio, B magnitude unit^{-1}

0.3   0.6   0.9   1.2   1.5

(c)

Fractal dimension of epicenters, C

0.50   0.75   1.00   1.25   1.50

Fig. 1. Global distribution of coefficients of Unified Scaling Law for Earthquakes (USLE).
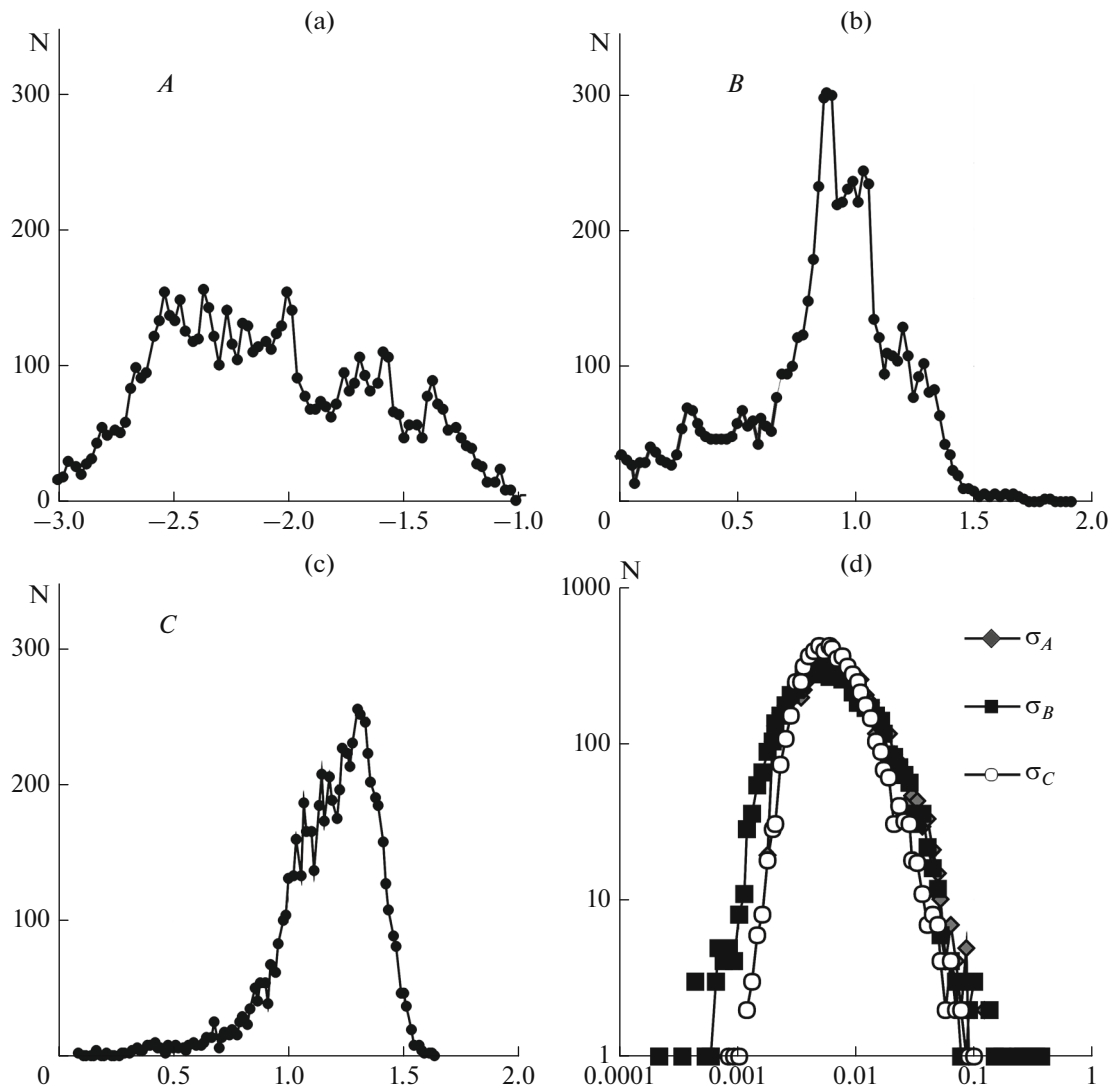
Fig. 2. Histograms of global distribution of USLE parameters: (a) A; (b) B; (c) C; (d) σ_A, σ_B, σ_C (log-log plot).

a critical transition associated, inter alia, with the occurrence of a strong earthquake.

To give an example, we present local estimates of the USLE parameters for the Friuli-Venezia Giulia autonomous region of Italy (Nekrasova et al., 2018). The estimates are based on the regional earthquake catalog of the Istituto Nazionale di Oceanografia e Geofisica Sperimentale (OGS) (National Institute of Oceanography and Applied Geophysics) for the period from 1996 to March 2018. The USLE coefficients are estimated from the events starting from magnitude 2.0 for the spatial cells with a linear size of 1/16 of the Earth's meridian (about 6.9 km) and five levels of the spatial hierarchy. The degree of detail and measurement accuracy of the local catalog allowed the USLE coefficients to be estimated for successive six-year intervals shifted by one year. Figure 3 shows the values of coefficients A, B, and C for two six-year

intervals: the initial interval 1996−2001 for which reliable estimates are obtained in 214 cells and the final interval 2012−2017 for which reliable estimates are obtained in 311 cells. Figure 3 also shows the projections of these coefficients on the coordinate plane. It is worth noting that in the estimates for the initial six-year period, the earthquake that occurred on April 12, 1998 (the region's strongest one during the studied period) and its numerous aftershocks undoubtedly increased the values of coefficients A and B and at the same time reduced the values of coefficient C in cells pertaining to the region of high concentration of the epicenters. In the absence of strong events from 2012 to 2017, the values of the USLE coefficients are more concentrated in the vicinity of 0 (coefficient A), from 0.6 to 1.0 (coefficient B) and above 1 (coefficient C). The complicated 3D pattern of relative positions of the USLE coefficients' values indicates a non-trivial cor-
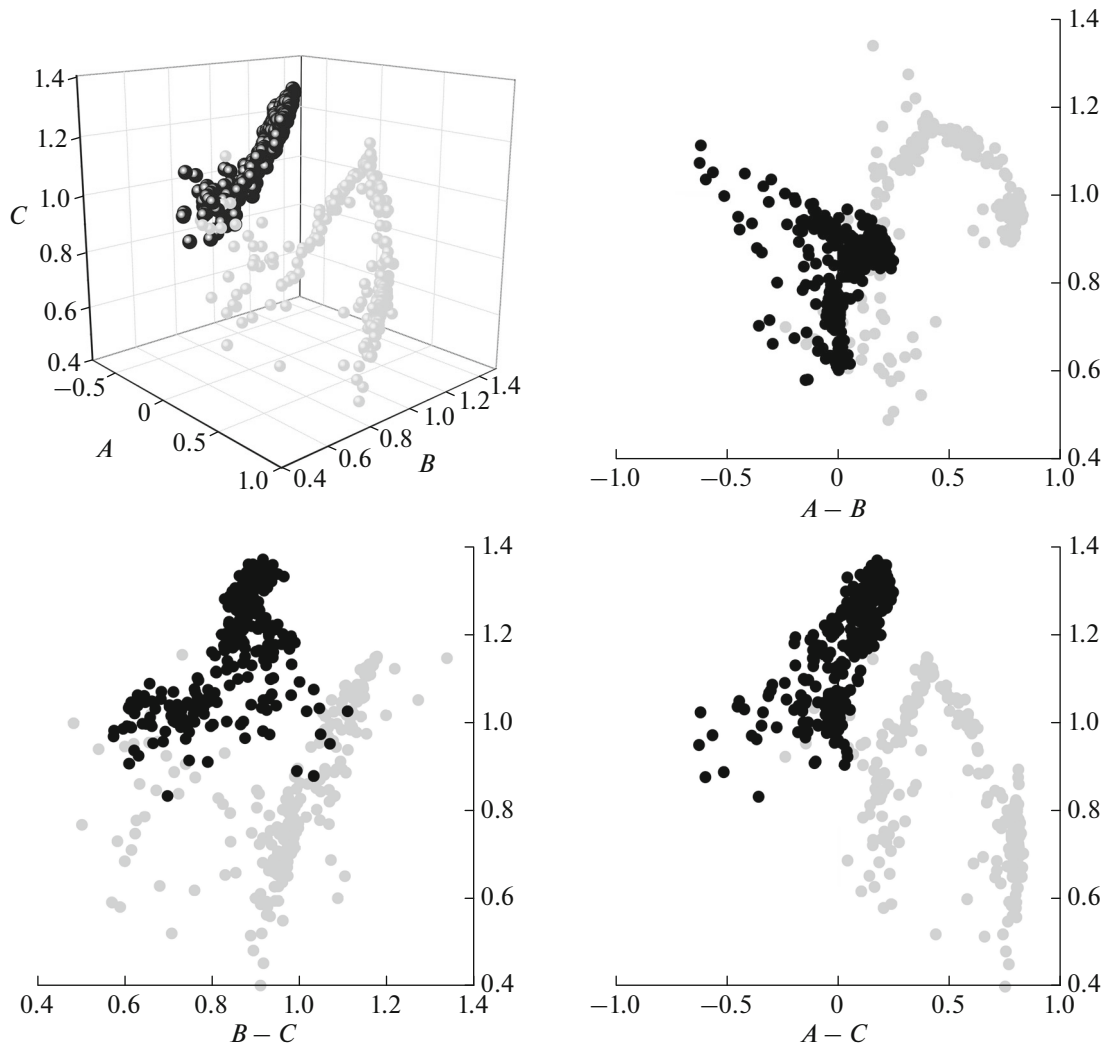
Fig. 3. USLE coefficients in Friuli–Venezia Giulia autonomous region, Italy, for initial (2001, gray markers) and final six-year time intervals (2017, black markers).

relation between the parameters and a substantial diversity of the characteristics of seismicity rate within the study region; it also apparently testifies to the significant variability in the dynamics of the time sequence of the earthquakes.

According to (Nekrasova et al., 2018), the critical transition associated with the earthquake of April 12, 1998 is characterized by the change in the USLE control parameter by a factor of 1.5 from the average η level below 0.2 in 1997 to above 0.3 in 2002–2004.

BUILDING THE SEISMIC HAZARD MAPS BASED ON USLE

The regional estimates of coefficients A, B, and C can be used for determining and mapping the maximum magnitude expected in a given time interval based on USLE. Indeed, according to (2), the number of events of given magnitude M_j expected in T years is

$N_T(M_j) = T \times N(M_j, L_0)$ where L_0 is the linear size of the cell for which the mapped USLE coefficients are determined. The maximum M_j values for which $N_T(M_j) \geq p$ (for $0 \leq p \leq 1$) can be considered as the magnitudes of the strongest earthquakes expected in each cell of the map with probability p in T years (Parvez et al., 2014).

Clearly, the reliability of seismic hazard maps (in particular, the USLE-based ones) increases with the involvement of the recognition results for the strong earthquake-prone areas (Kossobokov and Soloviev, 2018) and reliable data for the historical and paleo-earthquakes. In the territory of the Russian Federation, seismic hazard maps based on the results of USLE and pattern recognition methods in combination with the data of the historical catalog of seismic events were constructed for the Crimea and Greater Caucasus, Cisbaikalia,

Altai, and Sayan (Nekrasova et al., 2015; Kossobokov and Nekrasova, 2018a; 2018b).

As an example, let us more thoroughly consider the recent results for the territory of Altai and Sayan which were obtained with the additional use of morphostructural zoning (MSZ) maps and the recognition of the areas prone to the strong earthquakes with magnitudes $M \geq 6.0$ (Gorshkov et al., 2018). Among the 63 MSZ intersections of the region, Fig. 4a shows 19 ones recognized as highly seismic for the territory of Altai and Sayan including the sites where, according to the historical data, no such events were observed. Figure 4b shows the data on the historical earthquakes for the studied territory since 1734 (Kondorskaya et al., 1982) that were used in (Gorshkov et al., 2018). The map of the maximum magnitude M_{max} (Fig. 4c) expected with the occurrence probability of 10% in a period of 50 years for the Altai and Sayan region was constructed based on (1) estimating the USLE coefficients in each of 207 spatial cells with a linear size of $0.25°$ containing at least two seismic events from the regional catalog for 1997−2015 compiled from the annuals "Northern Eurasia Earthquakes" in 1997−2009 (Starovoit, 2015) and "Earthquakes in Russia" in 2003−2015 (Malovichko, 2017); (2) spatial hierarchy with fourfold doubling; and (3) selecting the parameter p and T values corresponding to the widely used criterion of seismic hazard assessment in terms of ground shaking characteristics. The final seismic hazard map in terms of the maximum magnitude M_{max} for the Altai and Sayan region in Fig. 4d combines the maps shown in Figs. 4a, 4b and 4c; in the case when several estimates are concurrent at the same node, the maximum estimate is selected.

For constructing the USLE-based seismic hazard map of a territory in terms of site response, the M_{max} map needs to be transformed which can be done using the neodeterministic modeling of the variety of scenarios of the probable strongest earthquakes (Panza et al., 2001). The calculations can be simplified if we consider one of the empirical relations describing the attenuation of the ground motion from an earthquake. For example, for the peak ground acceleration (PGA), for each source cell with an expected earthquake of magnitude M_{max}, we calculate the acceleration caused by this event at the receiver point using the formula motivated by the non-deterministic earthquake modeling (Parvez et al., 2001):

$$Acc(M_{max}, D) = const \times g \times D^{-1.5} \times \exp(M_{max} - 5), \quad (3)$$

where D is the distance between the source and the receiver on the $0.25° \times 0.25°$, const = 6.0, $g = 9.81$ m/s^2 is the gravitational acceleration, and $\exp(x)$ is the (natural) exponent of x. The PGA value at a point is determined as the maximum acceleration calculated at this point over all the source cells of the studied territory.

COMPARISON OF SEISMIC HAZARD ASSESSMENTS BASED ON USLE, NEODETERMINISTIC, AND PROBABILISTIC MODELS

The results of the Global Seismic Hazard Assessment Program (GSHAP, 1992−1999) (Shedlock et al., 2000; Giardini et al., 2003) and the ongoing Global Earthquake Model (GEM) project aimed at refining the seismic hazard and seismic risk assessments for individual regions of the world based on the probabilistic approaches allow the comparison of the regional seismic hazard maps obtained based on ULE and retrospectively estimate the reliability of the results of the compared methods.

We compared each regional seismic hazard map constructed in terms of PGA based on USLE with the results of the GSHAP project (the archived data in the form of the ASCII files GSHPUB.dat are accessible at http://static.seismo.ethz.ch/gshap/gshpub.zip and contain the values on the General seismic zoning map of the Russian Federation OSR-97-A).

As an example, Fig. 5 shows the USLE-based maps of the probable ground shaking intensity in terms of PGA obtained for the Altai and Sayan region in the GSHAP project. The PGA calculations based on USLE are presented for the maximum expected magnitudes obtained for the Altai and Sayan region and described in the previous section. We note that the seismic hazard map constructed using the USLE approach (PGA$_{USLE}$) is more detailed and more contrasting than the map obtained for this territory in the GSHAP project (PGA$_{GSHAP}$). It has also been noted (Kossobokov and Nekrasova, 2011; 2018a; 2018b; Nekrasova et al., 2015) that the PGA$_{GSHAP}$ values fairly frequently contradict the real parameters of the strong earthquakes while the determinations obtained by the USLE approach are more consistent with the real data. For example, the PGA values at 131 epicenters of the earthquakes with magnitudes starting from 5.0 that occurred in the Altai and Sayan region from 1761 to 2017 are in 52 cases at least double the PGA values in the map obtained in the GSHAP project. Moreover, the ratio of the PGA at the epicenter to PGA$_{GSHAP}$ is larger than 4 in 26 cases and larger than 8 in 13 cases. Remarkably, the PGA$_{GSHAP}$ values at the epicenters of all the seven earthquakes with magnitudes of 7.0 and higher is at most half the values of the observed ground shaking, and the underestimation exceeds 4 for six and 8 for five strongest earthquakes of the region.

The USLE-based seismic hazard assessment in regions was not only conducted for a territory overall but also for individual large cities. Table 1 presents the results of seismic hazard assessment for eleven earthquake-prone cities with a population of more than 100000 people in the Altai−Sayan region (the data of the Federal State Statistics Service of the Russian Federation for 2016). In the Table 1, the two maximum values of the population, city area S, PGA$_{GSHAP}$ and
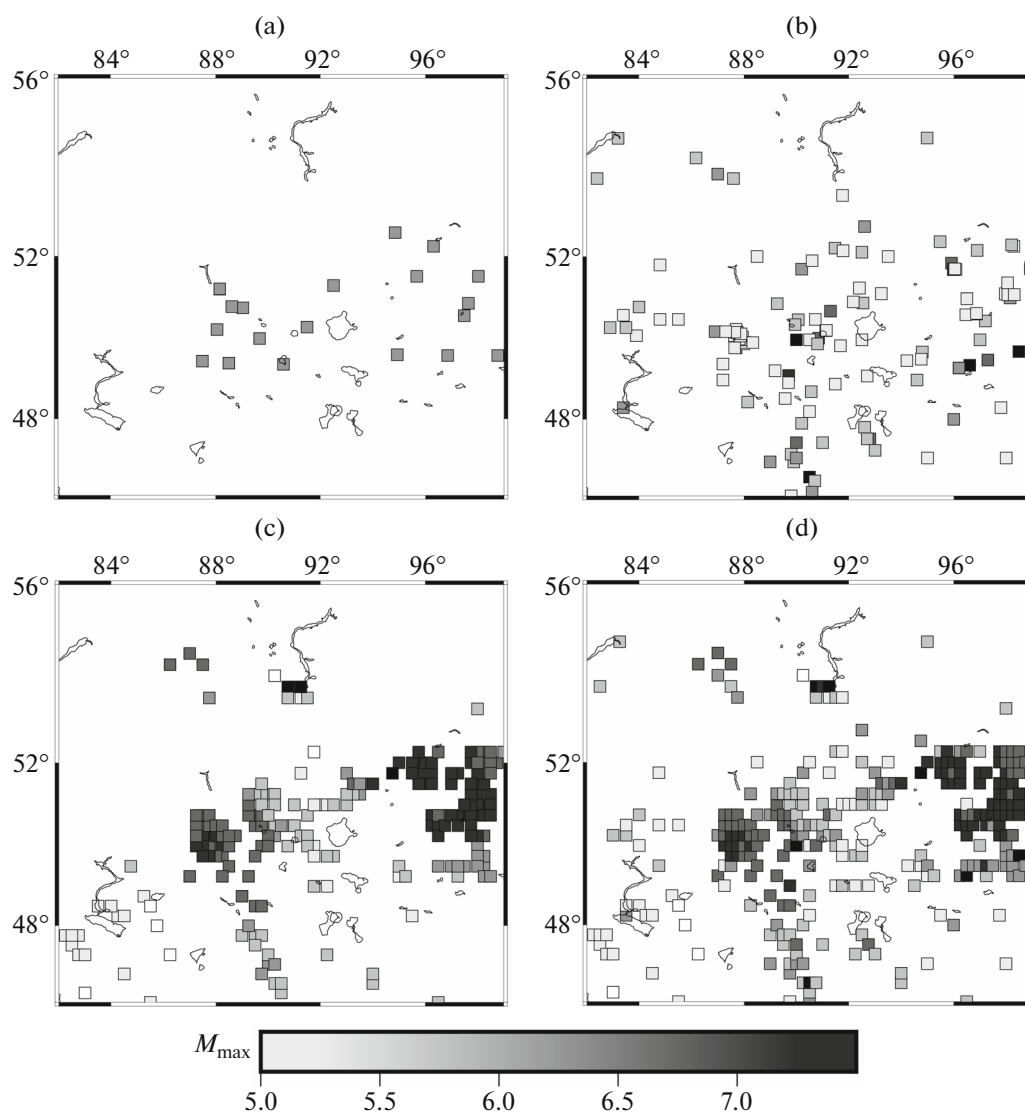
Fig. 4. Seismic hazard maps for Altai−Sayan region in terms of expected maximum magnitude M_{max} in cells of regular $0.25° \times 0.25°$ grid: (a) highly dangerous MSZ nodes recognized as prone to earthquakes of magnitude 6.0 or larger; (b) maximum observed magnitude in 1734−2017 from catalog (Kondorskaya et al., 1982) and USGS ANSS Comprehensive Earthquake Catalog (https://earthquake.usgs.gov/earthquakes/search/ cited September 18, 2017); (c) maximum expected M_{max} value calculated based on USLE and parameters $p = 10\%$ and $T = 50$ years; (d) combined M_{max} map.

PGA_{USLE} are highlighted in bold, giving a visual idea of the complex combinations of possibilities. For example, Novosibirsk, the most populated city in the region, halls in the zone of the minimal seismic hazard in the GSHAP map whereas the estimates based on USLE rank it fourth among the studied earthquake-prone cities. Kyzyl has the smallest area among the selected cities and ranks first as the most prone to the earthquakes according to PGA_{GSHAP}; according to PGA_{USLE}, it shares the first and second position in the list with the city of Abakan. It should be noted that the ratio of estimates PGA_{USLE} /PGA_{GSHAP} reveals unacceptable seismic hazard underestimation according to the GSHAP program in eight of eleven large cities in

the region (by a factor of four or even more, bold italics in the last column of Table 1).

In the territory of the Indian state of Gujarat where two devastating earthquakes occurred in the past 150 years (on June 16, 1819, $M_w \sim 7.8$, and on January 26, 2001, $M_w \sim 7.7$), a comparison can be made among several seismic hazard estimates obtained by different methods (Parvez et al., 2017). Figure 6 shows the seismic hazard maps in terms of the peak ground acceleration obtained using USLE, based on neodetermnistic calculations of the design ground acceleration (DGA) (Panza et al., 2001), and based on the probabilistic approach GSHAP. The PGA calculations were conducted for standard probability of exceedance of 10%
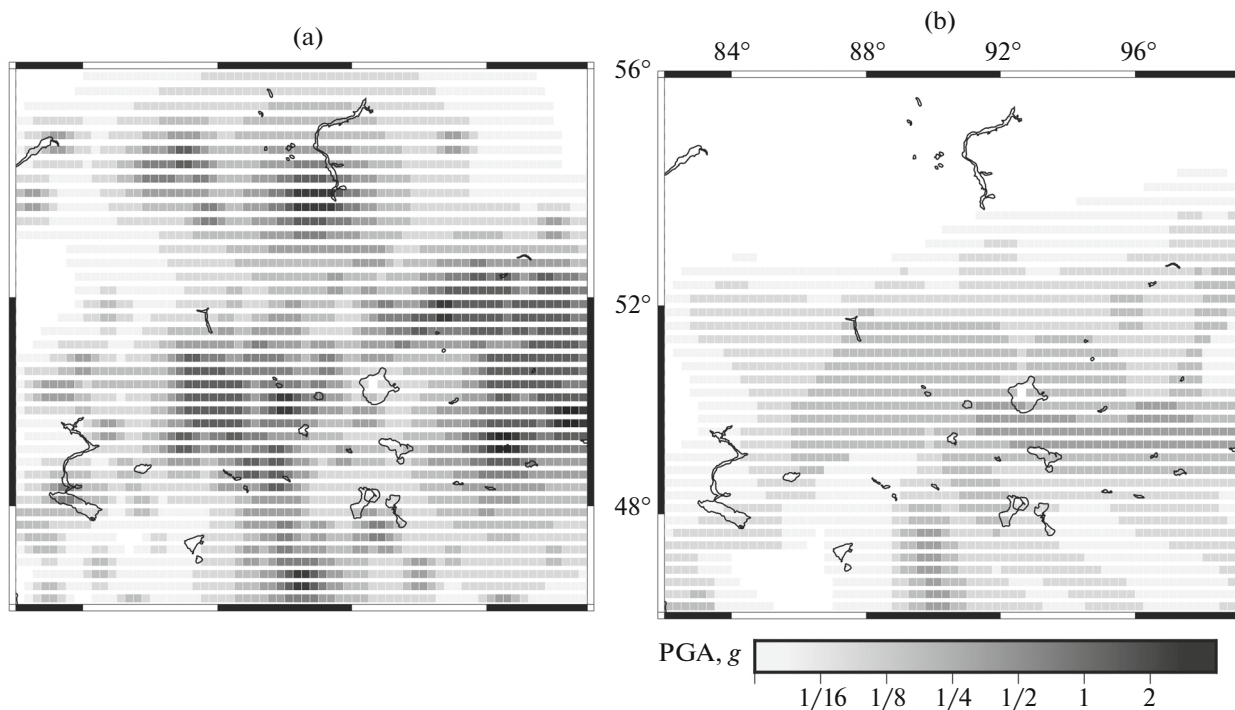
Fig. 5. Maps of peak ground acceleration from earthquake of magnitude M_{max} for Altai– Sayan region: (a) according to calculations based on USLE approach; (b) according to final GSHAP maps.

in 50 years (the map based on the USLE in Fig. 6a, the DGA 10% map in Fig. 6c, and the GSHAP map in Fig. 6d, respectively) as well as for the neodeterministic DGA assessment without limitation for the recurrence time and for DGA 2% with the recurrence time of 2475 years (Figs. 6b and 6d, respectively). The distribution of seismic hazard assessments in terms of PGA for all five maps is illustrated in Fig. 6c.

We note that for the state of Gujarat, the estimates of the most probable significant ground shaking of the order of g/8 and stronger by the standard DGA approach and based on the USLE methodology are consistent with each other, having discrepancies in the spatial distribution of strong ground shaking. The shaking intensity estimates based on three other approaches underestimate the seismic hazard for the

Table 1. Estimate of expected peak ground acceleration (PGA) for main cities of the Altai and Sayan region

| City | Population | S, km^2 | PGA, g | | PGA_{USLE}/PGA_{GSHAP} |
			GSHAP	USLE	
Abakan	165214	112.4	0.06	**>1**	**>16**
Achinsk	109155	103.0	0.02	0.15	**7.80**
Barnaul	612401	321.0	0.04	0.07	1.55
Biysk	210115	291.7	**0.10**	0.09	0.88
Kemerovo	532981	282.3	0.02	0.16	**7.85**
Krasnoyarsk	**1083865**	348.0	0.02	0.14	**6.04**
Kyzyl	109918	97.4	**0.20**	**>1**	**>5**
Novokuznetsk	547904	424.3	0.05	0.61	**11.89**
Novosibirsk	**1602915**	**505.6**	0.02	0.29	**11.71**
Oskemen*	321251	**540.0**	0.06	0.24	**4.27**
Tomsk	524669	297.2	0.02	0.07	3.32

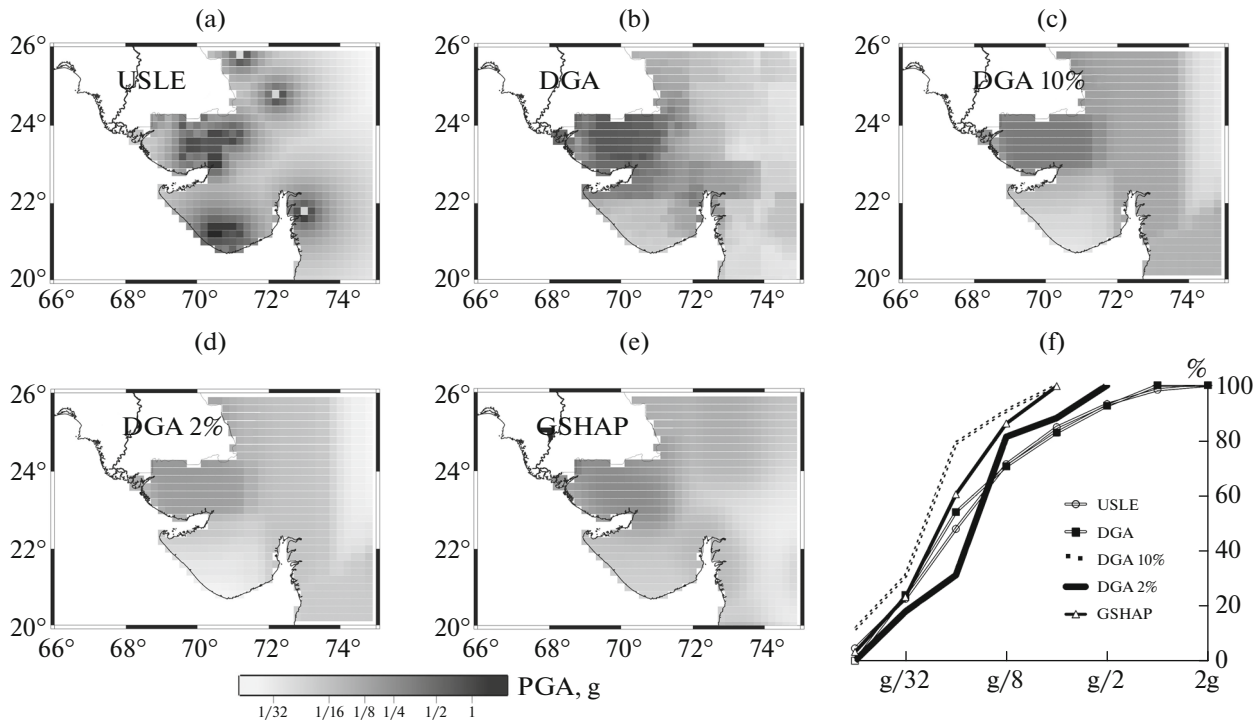* Oskemen (Kazakhstan) was formerly named Ust-Kamenogorsk.

Fig. 6. Maps of the maximum expected PGA from earthquake for state of Gujarat, India. Note: (a) according to calculations based on USLE approach; (b) according to standard calculations of neodeterministic estimates of ground shaking; (c) according to calculations of neodeterministic estimate of ground shaking for 475 years; (d) according to calculations of neodeterministic estimate of ground shaking for 2475 years; (e) according to final GSHAP maps; (f) distribution of estimates of maximum expected acceleration for maps (a)−(e).

territory of the state by a factor of 2−4, and in the case of ground shaking commensurate with that recorded during the earthquake of 2001, the underestimation of the GSHAP and DGA 10% determinations reaches a factor of 8.

SEISMIC RISK ESTIMATE BASED ON USLE

The USLE approach can also be used for estimating the seismic risk. We recall that mathematically, any type of risk is the result of a convolution of the hazard with the hazard-prone object and with the vulnerability of this object:

$$R(s) = H(s) \otimes O(s) \otimes V(O(s)), \qquad (4)$$

where s determines the spatial location and can be a point, a line, or a certain area on/beneath the Earth' surface; $H(s)$ is the natural hazard; $O(s)$ describes the objects at rick at location s; and $V(O(s))$ describes the vulnerabilities of these risk objects. (Here, $H(s)$, $O(s)$, and $V(O(s))$ can be time dependent.)

Let us illustrate the general problem-oriented approach and the variety of factors affecting risk estimation by the example of seismic risk estimates using demographic data on the population. We consider the above seismic hazard assessments for the state of Gujarat, India. In this example, as a convolution we use multiplication although a more complex functional dependence is also possible. Figure 7 shows the distributions of estimates of model risks: (a) with equal vulnerability of each individual, $R_i(s) = H(s) \cdot \int_s P$, where $\int_s P$ is the integral of population density in cell s, i.e., the number of people within the cell area s; (b) with personal vulnerability linearly increasing with the population density in a given location, $R_{ii}(s) = H(s) \cdot \int_s P \cdot P$; (c) and (d) correspond to two nonlinear assumptions about vulnerability, depending on population density, $R_{iii}(s) = H(s) \cdot \int_s P \cdot P^2$ and $R_{iv}(s) = H(s) \cdot \int_s P \cdot P^3$, respectively. The values of each of the four model risks are indicated in the units normalized to the corresponding maximum value on the map. As expected, the distribution of risks follows the trends of seismic hazard distribution; therefore, the USLE approach provides the most conservative estimates while the GSHAP and DGA 10% estimates seem to be too optimistic if not supported by the additional subjective assumptions used as the arguments. At the same time, it becomes clear that in the areas with highest population concentration, as the vulnerability becomes less dependent on the population density, the
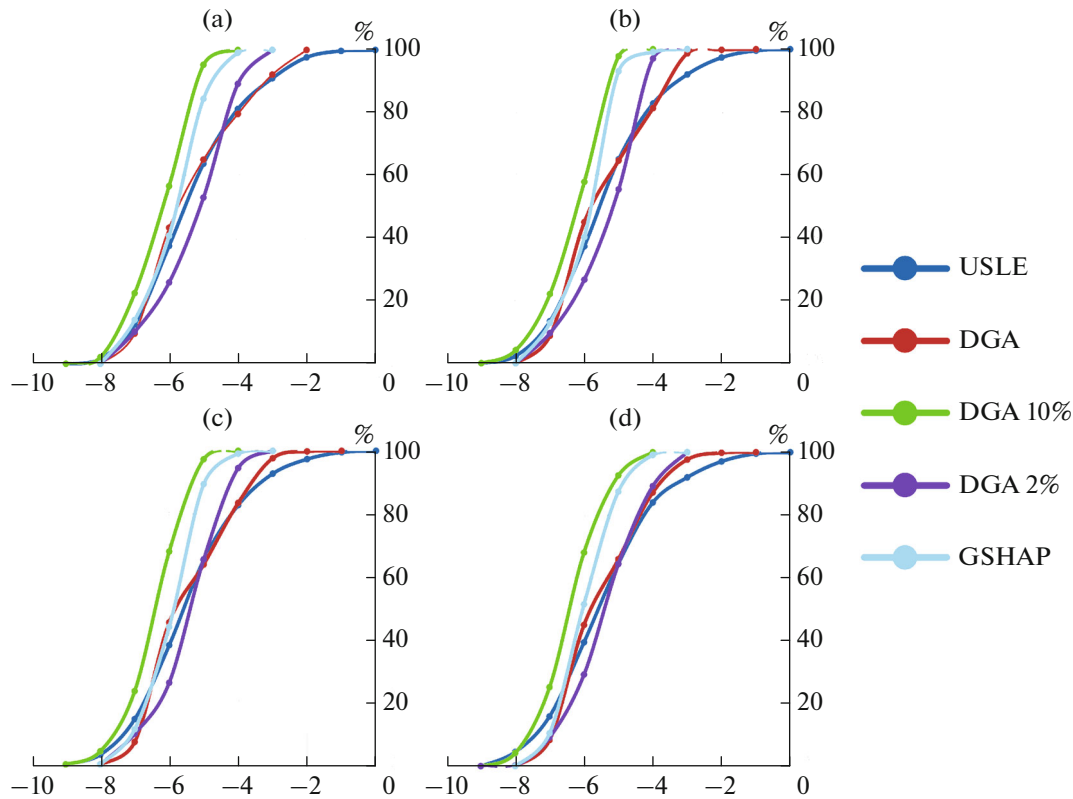
Fig. 7. Distribution of seismic risk estimates $R(s)$ for population of Gujarat state, India, for five models of seismic hazard assessment $H(s)$. Note: (a) $R_i(s) = H(s) \cdot \int_s P$; (b) $R_{ii}(s) = H(s) \cdot \int_s P \cdot P$; (c) $R_{iii}(s) = H(s) \cdot \int_s P \cdot P^2$; (d) $R_{iv}(s) = H(s) \cdot \int_s P \cdot P^3$.

territory of the increased risk diminishes. This example is a fairly natural and striking demonstration of how a vulnerability factor can change the very perception of risk.

CONCLUSIONS

The estimates of seismic hazard and associated risks are currently rather uncertain. In the absence of the data for many thousands of years, the probabilistic estimates of the recurrence of the earthquakes remain scientifically unsound. Our very brief review of one new approach to the problem, which is based on USLE, unveils the possibility of the much higher risks than in the existing widely used maps of probabilistic seismic hazard assessment. This approach takes into account the natural fractal distribution of earthquake locations together with the tectonic data and the pattern recognition arguments. The studies in this field which are currently conducted at the Institute of Earthquake Prediction Theory and Mathematical Geophysics of the Russian Academy of Sciences make their modest contribution to the urgent revision of the maps of probabilistic seismic hazard estimates by improving the basic methodologies. Obviously, these works do not currently allow for the real economic and social factors of risk assessment, disregard the role of the topography and soil effects, and set aside the source size and focal parameters of the large and/or complex seismic events. These important considerations should be taken into account in the future practical assessments and mapping of seismic hazards and risks.

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