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ALGORITHM MEE (MAP OF EXPECTED EARTHQUAKES): SUMMARY OF THE 30-YEARS TEST AND RECENT RESULTS

The Map of Expected Earthquakes (MEE) algorithm was suggested in the mid-1980s by *G.A. Sobolev, T.L. Chelidze, L.B. Slavina, and A.D. Zavyalov*, the most active members of a special informal team called QCSA (Quick-Look Comparative Seismic Analysis). Over the last 30 years, the algorithm has been tested in a variety of seismically active regions all over the world, including the Caucasus, Kamchatka, the Kopet Dag, the Kyrgyz Republic, Southern California, Northeast and Southwest China, Greece, West Turkey, the Kuril Islands, and New Zealand. The average predictive effectiveness for these regions was J_{MEE}=2.56 and 3.82, with conditional probability value $P(D_1|K)$=70% and 90%, respectively, selected as an alarm level. This being the case, 68% and 41% of predicted earthquakes occurred in the zones with these levels of conditional probability; the area of alarm zones was 30% and 14% of the total area of observations, respectively.

The most recent paper was the first to use the MEE (Map of Expected Earthquakes) medium-term earthquake prediction algorithm to develop maps of expected earthquakes in a classical area with a transient seismic regime, namely the Koyna-Warna reservoir site (India).

The local earthquake catalogue for this area, covering the period of time from 1996 to 2012 (approximately 17 years) and including 4,500 earthquakes with M_L=0-6.5 magnitudes that occurred in the depth range of H=0-20 km, was used as the database for this work. Linear dimensions of the seismic area are 40×60 km. Approximately half of all earthquakes included in the catalogue are the aftershocks of earthquakes with $M_L \geq 4$. They were not excluded from the catalogue when calculating time and space distributions of predictor parameters and expected earthquake map values. Magnitude M_c=2.1 selected as a representative magnitude,

all subsequent calculations of seismic parameters used all earthquakes with $M_L \geq 2.1$ magnitudes registered continuously starting from 1996 over the entire Koyna-Warna area.

A standard set of seismic predictor parameters (dynamic characteristics) used for expected earthquake mapping of seismically active regions with pronounced tectonic activity was used for the Koyna-Warna area: *b*-value of the magnitude-frequency relationship, number of earthquakes in the form of relative seismic quiescences *Nq* and in the form of seismicity activations *Na*, released seismic energy in the form of energy quiescences *Eq and in the form of energy activations Ea*, and density of seismogenic ruptures K_{sf}. Time and space distributions of seismic parameters were calculated in half-overlapping rectangular grid cells ΔX×ΔY. As the base case scenario, we selected the dimensions of a spatial cell equal to 10×10 km. When calculating K_{sf} parameter distributions, the cell dimensions were 5×5 km. The sliding time window value ΔT_t for calculation of current predictive characteristics was selected as ΔT_t =3 years with the shift Δt =3 months.

Earthquakes with $M_L \geq 4.0$ were selected as targets for prediction since they are of interest not only from a scientific point of view, but also from a social and economic point of view. In 1996-2012, 26 such earthquakes and their groups occurred in the area under study. This was enough to obtain retrospective statistical estimates for each precursor used. Among these earthquakes, four groups of events that include earthquakes with $5.0 \leq M_L < 5.5$ were the largest. Seven groups include earthquakes with $4.5 \leq M_L < 5.0$. Unconditional probability of a major earthquake in the grid cell was estimated as $P(D_1)$=0.1698.

Effectiveness of most predictive characteristics *J* for the selected alarm levels turned out to be more than 3, i.e. these characteristics can be regarded as *"quite useful"*. For just one characteristic (*Ea*), effectiveness was about half as much and equal to *J* =1.58, which is classified as *"useful"*.

A series of 42 expected earthquake maps was developed for the Koyna-Warna area, from 1 July 2002 till 1 October 2012, with 3-month step and 2-year prediction periods for each map. The findings of using the MEE algorithm in a classical area with a transient seismic regime for the first time were very encouraging. They showed that its prediction reliability was quite high and equal to J_{MEE}=2.76. Zones with conditional probability levels $P(D_1|K)$≥90% experienced 56.3% of all earthquakes with M_L≥4.0. The alarm area was 20.4±8.4% of the total area of observations. The MEE algorithm was particularly efficient in predicting the largest earthquakes in the Koyna-Warna area that occurred during the retrospective prediction period. At a later stage, more accurate adjustment of algorithm parameters may improve the overall prediction reliability.

The prediction can be verified in real time using the most recent expected earthquake map in the series for the period from 1 October 2012 to 30 September 2014.

Therefore, integral predictive reliability estimates obtained when the MEE algorithm was used for the Koyna-Warna reservoir site are close to the average values of these parameters for all previous seismically active regions. These findings may be considered proof of the flexibility of the proposed algorithm.