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REVIEW

Challenges posed by disasters due to earthquakes can result in negative impacts for the sustainable development. Since the beginning of the 21st century the impacts of earthquake-related disasters have risen rapidly, e.g., the 2004 Sumatra-Andaman earthquake and induced tsunamis, the 2005 Kashmir earthquake, the 2008 Wenchuan earthquake and induced landslides, the 2011 Tohoku earthquake and induced tsunamis and flooding, and the 2015 Nepal earthquake and landslides. Understanding of earthquake disasters comes from recent advances in basic sciences, engineering, and applied research including comprehensive seismic hazard assessments combining knowledge on seismology, geology, geodesy, geodynamics, electro-magnetism, hydrology, and soil properties with modelling tools and forecasting.

In this framework, the D.Sc. dissertation by Dr. Rashid Burtiev is a bright example of combination of the knowledge of seismology with mathematical approaches to assessment of seismic hazards. His study is related to seismicity of the Vrancea region, where large intermediate-depth earthquakes cause destruction in Romania and shake central and eastern European cities several hundred km away from the hypocentres of the events. Dr. Burtiev has developed a new approach to seismic hazard assessment and applied this approach to analyse seismic hazard in several regions.

The approach includes four principal steps: (i) determination of seismic zones; (ii) construction of the Markov model of seismic process for assessing the earthquake parameters required for

hazard analysis; (iii) the determination of the parameters of the ground motion prediction equations; and (iv) development of the algorithm for seismic hazard assessment in a particular site.

The major results of the work, which I would highlight, are

- The author showed the seismic activity interaction between earthquake-prone regions in Balkans as statistically significant. The statistical analysis illustrates that earthquakes tend to occur at the places, where they have already occurred (actually, this is an obvious fact in terms of geophysics, as earthquake occurs mostly on existing faults rather than at newly created faults). Also, the zone of a potential earthquake and the probability of the earthquake occurrence can be determined from the marginal distribution of seismic zones.
- The author shows a weak probabilistic relationship between the earthquake magnitude and the occurrence time between earthquakes in the Vrancea region. This result confirms the earlier results related to modeling of earthquake occurrences in the region (Panza et al., 1997; Soloviev et al., 1999, 2000), where it was shown the difficulties in assessment of reoccurrence time of large earthquakes in the Vrancea region.
- An algorithm for seismic hazard assessment was developed and applied to analysis seismic hazard in Bulgaria, Romania, Moldova and Turkey. Particularly using a cluster analysis, active seismic zones in Romania and in Turkey were identified, and a Markov model of seismic process was developed for the identified zones to assist in seismic hazard assessment.

Despite some critical but constructive points of my detailed review (below), the dissertation presents the significant research work done by the authors for years, the work is scientifically and statistically sound, and the results can contribute to development of seismic hazard assessment.

Detailed review

1. Chapter 1 overviews the research done in the area. My major concern is that the chapter does not present a state-of-the art science in seismic hazard assessment, neither in general nor specifically for the Vrancea region. The most references are rather old for the intensively developing area of research. A significant progress in this area of research is made for the last decade with many publications, but there are almost no references to the works in the area done. I may realise some difficulties related to an access to foreign scientific literature in Moldova, but it is not a reason to do not refer to the previous significant work done in this research area. Moreover, today using Internet it is possible to see at least abstracts of the work; also, many papers are accessible in ResearchGate portal. This chapter does not present the scientific gaps in this area of research, which the author would like to fill. Particularly, the work discusses the limitations associated with the available catalogues as not yet resolved problem and suggest that modelling can assist. Actually, Sokolov and Ismail-Zadeh (2015) published a paper presenting a

new approach to probabilistic seismic hazard assessment (PSHA) based on recorded, historical and modelled earthquake, which significantly improves the results of PSHA.

2. Another concern is related to the fact that the author did not compare the results obtained in this dissertation (e.g., seismic hazard maps) with those obtained earlier by other authors (e.g., Sokolov et al., 2004, 2005; Ismail-Zadeh et al., 2007). This makes difficult to assess the novelty of the work compared to earlier research. Such a comparison could present pros and contras of the developed approach.
3. In Chapter 2, the authors use a formal cluster analysis to identify seismic zones. However, it was not showed why the proposed approach in identifying clusters using statistical methods is better than geological, seismological and morphological identification of the clusters. It is evident that significant earthquake and their aftershocks occurs mostly at known faults and the clustering of crustal earthquake should consider the information about the structure and composition of the crust. A purely statistical approach supplemented by the geoinformation will provide more reliable results. A scientific drawback of the chapter is that the author did not discuss why the clustering is needed in the PSHA and how different clusters or results of different clustering can influence the seismic hazard assessment. A technical drawback of the chapter is that the overviewed methods for cluster analysis were not compared using the same region (e.g., the Vrancea region) to see their efficiency and disadvantages.
4. Chapter 3 concerns statistical analysis of earthquake catalogues. Particularly the author transforms different magnitude scales to mb scale, which is important for uniform analysis of seismic hazard. Meanwhile, there is no comparison between the proposed transformation relationships and those developed earlier. Again, this makes difficult to assess the novelty of the proposed transformations and their significance. Also, a geophysical interpretation of the weak statistical correlation between the earthquake magnitudes and their depth is non-convincing.

   Section 3.11 discuss the correlation between Vrancea earthquakes and the number of sunspots, which seems to be a strange appearance in the chapter.
5. In chapter 4, the author presents models of seismic processes. Too much technical chapter is not well written to appreciate all findings; an example, the author does not explain some terms used in the chapter (e.g. an Erlang distribution; this distribution is not usual for statistical analysis of seismic processes). The author should provide the evidences that the same Markov model can be used for crustal and intermediate-depth earthquakes in the Vrancea region. And in general, the author should provide more evidences that a continuous Markov chain can be considered as a statistical model for Vrancea earthquakes. There is a statement in the chapter that the Markov model can assist in identification of migration of earthquakes along seismic belts. However, it is not clear from the chapter how it can be done.

6. Chapters 5 and 6 are dedicated to analysis of earthquake intensity in the Vrancea region and non-stationary regime of seismic flow (using time series), respectively. Although the both chapters present studies related to statistical analysis of earthquake in the region, the chapters are quite marginal to the main topic of the dissertation, seismic hazard assessment.
7. In Chapter 7, the author presents the approach to PSHA and some results of the method for hazard assessment. The author states that at the second step of the PSHA, the Markov model is constructed to predict the magnitude, place and the mean value of earthquakes in the specified site for a prescribed time interval. It is not clear from this chapter (as well as from chapter 4) how well the model can do so, compared to other models.

Also, I made intensive suggestions for minor revision in the text of the dissertation and forwarded them to Dr. Burtiev. Particularly, there are some paragraphs appearing in the text of the dissertation several times. Another concern was the mixture of mathematical formulation of the problem with purely seismological statements without showing the link between each other.

Finally, **the submitted work meets all the requirements set by the Ministry of Education and Science of Ukraine to a Doctor of Science dissertation, and its author, Burtiev Rashid Zetovich, deserves assigning the desired degree of Doctor of Physical and Mathematical Sciences on specialty 04.00.22 – Geophysics.**

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