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Rating Seismicity In Terms of Radiated Energy of Earthquakes

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Abstract

In the world of seismology, a major tool for seismicity study is the Gutenberg – Richter (G-R) relation whereby the G-R constants a and b are determined from earthquake catalogue to assess the seismicity of the region of interest. However the G-R relation does not accommodate information about the spatial coverage of the region concerned hence it will not suitably compare seismic activities of two or more regions that have unequal spatial coverage. Moreover, the method breaks down for any region where earthquake events are virtually of the same magnitude since constants a and b are indeterminate in this case. In addition the relation gives the rate of seismicity in terms of the total number N of earthquakes which makes a region having unusually few but large earthquakes to be underestimated. In this work, two mathematical models for rating seismicity in terms of radiated energy per unit area per unit time of earthquakes in a given region over a period of time were developed. One of the models takes care of situations where the G-R constants may not be defined. The two models were applied to ten regions in the world seismic zones. Both models rated the seismicity of the regions in the same order that is different from rating obtained from the a value of the G-R relation.

Keywords: Earthquakes, seismicity, Gutenberg – Richter's relation, radiated energy

Introduction

Seismicity is the world -wide or local distribution of earthquake epicentres in space and time. It is a general term for the number of earthquakes in unit time, or for a relative earthquake activity. It is very obvious that the rate of earthquake occurrence varies from one region to another. Some regions are known to be very active; some are moderately active while some are inactive. However, in the absence of a suitable method of describing the manner of occurrence of earthquakes with respect to time and space, comparison of seismicity of any two regions could be difficult. The empirical formula: LogN(M) = a - bM known as the Gutenberg-Richter (G-R) magnitude-frequency relationship after Gutenberg and Richter (1954) is a common tool in seismicity study The constants a and b,usually referred to as the G-R constants are positive and real. For a certain region and time interval, the G-R relation provides the number of earthquakes, N, with magnitudes greater than or equal to M, **a** describes the seismic activity; b which is typically close to unity for the whole earth, describes the relative abundance of large to smaller shocks. The implications of several properties of the Earth interior as well as pattern of occurrence of earthquake clusters on the b- value has been extensively studied (Nakaya, 2004; Mogi, 1962; Suyehiro et al., 1964). In its original form, G-R relationship was based on the seismicity of the whole Earth but over the years, it has been found to fit into regional seismicity and other studies. E.g. Molchan et. al (1999) used the frequency-magnitude relation to construct a multi-scale seismicity model for the main shock in seismic risk assessment. The use of G-R relationship for studying regional seismicity has the following limitations:

1. It does not include information about the geographical area covered by the epicenters of earthquakes so it is possible to have the same values of a and b for two regions of different geographical areas; this implies that information about the clustering or sparseness of epicentres is lost.
2. It assumes that both constants a and b can be determined. However, occurrence of earthquakes with close magnitude range within a region of interest will yield a situation where the constants are indeterminate since G-R curve will be almost parallel to the vertical axis. In this work, we develop two mathematical models for rating the seismicity of any region over a period of time. The models take care of the limitations of G-R relation. It has an additional advantage of rating seismicity from energy of the earthquakes and yield a numerical value for the seismicity as is the case for earthquake magnitudes. This approach provides a better platform for comparing seismic activities of two or more regions.

Methodology

Model 1. This takes care of situations where the G-R constants are indeterminate. Considering an arbitrary region of coverage area A, where N earthquakes have occurred over a period T, total radiated energy per unit area per unit time is defined as:

$$\Im_1 = \sum_i^N E_i / TA$$

where E_i is the energy radiated by the *i*th earthquake.

The E_i was expressed in terms of earthquake moment magnitude m_i as $E_i = 10^{(1.5m_i + 11.8)}$. (Gutenberg, 1956; Lowrie, 1997) A second model, $\Im_2$, which incorporates the G-R constants was developed by dividing T into k equal sub-periods, and substituting for m in the G-R relation to yield:

$$\Im_2 = \frac{1}{TA}\sum_{j=1}^{k}\frac{10^{1.5a_j/b_j}}{N_j^{1/b_j}} \times 10^{11.8}$$

where aj and bj are the G-R constants for each sub - period k

The two models were applied to fifty-year (1956 - 2005) earthquake data for 10 selected regions in the world seismic zones and were rated accordingly.

Results

The two models ratted the seismicity of the regions in the same order which is different from the rating obtained by using the a - value of the G –R relation.

Conclusion

The models could suitably categorise seismic activities of two or more selected areas in terms of energy rather than number of earthquakes which the G-R a-value represents. Counting earthquakes of different magnitudes together is equivalent to combining unlike terms since a single large earthquake is equivalent to thousands of small earthquakes

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