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Multidimensional earthquake frequency distributions consistent with self-organization of complex systems: The interdependence of magnitude, interevent time and interevent distance

A. Tzanis (1) and F. Vallianatos (2)

(1) University of Athens, Geophysics and Geothermy, Zografou, Greece (atzanis@geol.uoa.gr), (2) Technological Educational Institute of Crete, Laboratory of Geophysics and Seismology, Chania, Greece (fvallian@chania.teicrete.gr)

It is well known that earthquake frequency is related to earthquake magnitude via a simple linear relationship of the form logN = a – bM, where N is the number of earthquakes in a specified time interval; this is the famous Gutenberg – Richter (G-R) law. The generally accepted interpretation of the G-R law is that it expresses the statistical behaviour of a fractal active tectonic grain (active faulting) – the relationship between the constant b and the fractal dimension of the tectonic grain has been demonstrated in various ways.
The story told by the G-R law is, nevertheless, incomplete! It is now accepted that the active tectonic grain comprises a critical complex system, although it hasn't yet been established whether it is stationary (Self-Organized Critical), evolutionary (Self-Organizing Critical), or a time-varying blend of both. At any rate, critical systems are characterized by strong interactions between near and distant neighbours. This, in turn, implies that the self-organization of earthquake occurrence should be manifested by certain statistical behaviour of its temporal and spatial dependence.
A measure of temporal dependence is the time lapsed between consecutive events above a magnitude threshold over a given area (interevent time). A measure of spatial dependence is the hypocentral distance between consecutive events above a magnitude threshold over a given area (interevent distance). The statistics of earthquake frequency – interevent times have been studied by several researchers, albeit frequently on the basis of different definition for the interevent time. The statistics of earthquake frequency – interevent distance is still terra incognita. Herein we present a multidimensional analysis of the statistical behaviour of frequency – magnitude – interevent time, frequency – magnitude – interevent distance and frequency – interevent time – interevent distance. We demonstrate that earthquake frequency is multiply related, not only to magnitude as the G-R law predicts, but also to the interevent time and distance by means of well defined power-laws. We also demonstrate that interevent time and distance are not independent of each other, but also interrelated by means of well defined power-laws. We argue that these relationships are universal and valid for both local and regional tectonic grains and seismicity patterns.
Eventually, we argue that the four-dimensional hypercube formed by the joint distribution of earthquake frequency, magnitude, interevent time and interevent distance comprises a generalized distribution of the G-R type which epitomizes the temporal and spatial interdependence of earthquake activity, consistent with expectation for a stationary or evolutionary critical system. Finally, we attempt to discuss the emerging generalized frequency distribution in terms of non-extensive statistical physics.

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