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Generalized multidimensional earthquake frequency distributions consistent with Non-Extensive Statistical Physics: An appraisal of the universality in the interdependence of magnitude, interevent time and interevent distance

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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 complexity and 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 strong line of evidence suggests that G-R law is a limiting case of a more general frequency–magnitude distribution, which is properly expressed in terms of Non-Extensive Statistical Physics (NESP) on the basis of the Tsallis entropy; this is a context natural and particularly suitable for the description of complex systems. A measure of temporal dependence in earthquake occurrence is the time lapsed between consecutive events above a magnitude threshold over a given area (interevent time). A corresponding 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 vs. interevent time have been studied by several researchers and have been shown to comply with the predictions of the NESP formalism. There's also strong line of evidence that the statistics of frequency vs. interevent distance is also compliant with NESP. Finally, recent work has indicated that on the assumption that the statistical distributions of Magnitude M and Interevent Time Δt and Interevent Distance ΔD are due to independent processes in the sense that the joint probability p(M, Δt, ΔD) factorizes into the probabilities of M, Δt and ΔD, i.e. p(M,Δt,ΔD)= p(M)p(Δt)p(ΔD), 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 consistent with NESP. This means 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 complex (stationary or evolutionary) critical system.

The above findings have attributes of universality, i.e. they are expected to hold true at all spatial, temporal and magnitude scales. The present work is an empirical attempt to explore the hypothesis of universality by investigating their validity and applicability to regional seismicity data from different seismotectonic regions of the world. Hitherto, the results are encouraging and appear to confirm the hypothesis.

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