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Seismic Hazard estimation and non extensive thermodynamics

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In seismology there is a sustained interest in the fractal nature and the possible power-law behaviour of earthquake. The non-extensive statistical mechanics pioneered by the Tsallis group [Curado and Tsallis, 1991; Lyra and Tsallis, 1998; Tsallis, 1988; Tsallis et al., 1995; Tsallis and Bukman, 1996; Tsallis et al., 1998] offer a consistent theoretical framework, based on a generalization of entropy, to analyze the behavior of natural systems with fractal or multi-fractal distribution of their elements. Such natural systems where long - range interactions or intermittency are important, lead to power law behaviour. We note that this is consistent with a classical thermodynamic approach to natural systems that rapidly attain equilibrium, leading to exponential-law behavior.

In the present work we apply the Tsallis entropy generalization that extends the traditional Boltzmann- Gibbs thermostatistics to seismic systems, where non-linearity, long-range interactions, long memory effects and scaling (fractal and multifractal) are important. The advantage of considering the Tsallis distribution is that based on an entropy principle, it can be related to statistical mechanics and reduces to the traditional BG statistical mechanics as a special case. Using a non extensive approach we conclude that under well defined conditions a power law behaviour exists, with $b(q)$ = (2-q)/(q-1). We analytically estimate, based on first principles, the interevent time probability function. In the frame of a non-extensive approach which is based on Tsallis entropy for the construction of the probability density function (PDF) and a phenomenological exponential expression for the damage function, we analytically calculate the seismic risk function. For the lowest size (i.e., energy level) the PDF can be deduced on the basis of the maximum entropy principle using BG statistics. In the low energy regime the correlation between the different parts of elements involved in the evolution of natural hazards are short–ranged. As the size (i.e., energy) increases, long range correlation becomes much more important, implying the necessity of using Tsallis entropy as an appropriate generalization of BG entropy. The power law behaviour for the PDF is derived as a special case,, leading to b-values being functions of the non-extensivity parameter q. The analysis of risk function dependence on the parameters of hazard PDF and damage function for earthquakes indicates that for earthquakes, the total risk arises from the largest events, as expected.

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