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Non-equilibrium systems, fractals, and phase transitions

Despite the fact that simple equilibrium distributions, including Gaussian or exponential distributions, are commonly used to model many natural and socio-economic systems, it could be argued that many systems in nature as well as in society are in fact far from equilibrium and that the use of these distributions is not appropriate and can lead to underestimating risk of extreme events. In fact, observations suggest that many systems exhibit critical properties such as power law scaling of their size-frequency distribution, and complicated distributions. In this paper we describe the general characteristics of such systems, and then we present two examples, one from natural, and one from social systems. The first example looks at the earth's magnetosphere. The magnetospheric characteristics commonly exhibit scaling properties, internal correlations, and noise common to phase transitions. This fact indicates that despite the fact that the common analyses focus on specific triggers, it is the overall state of the system that really matters. This is consistent with a body of theoretical and experimental research in space physics. In the socio-economic domain a prominent example heavily studied over the last decade relates to asymmetric warfare and terrorism. Again, both of these types of violence exhibit scaling properties common to critical systems. If they are indeed behaving as non-equilibrium, critical, systems, this would have implications for both the trend interpretation and for predictive analysis. We will discuss a body of work comparing modelling and observations that support this notion.