Predictability of extreme events in a branching diffusion model

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We propose a framework for studying predictability of extreme events in complex systems. Major conceptual elements -- hierarchical structure, spatial dynamics, and external driving -- are combined in a classical branching diffusion with immigration. New elements -- observation space and observed events -- are introduced in order to formulate a prediction problem patterned after the geophysical and environmental applications. The problem consists of estimating the likelihood of occurrence of an extreme event given the observations of smaller events while the complete internal dynamics of the system is unknown. We look for premonitory patterns that emerge as an extreme event approaches; those patterns are deviations from the long-term system's averages. We have found a single control parameter that governs multiple spatio-temporal premonitory patterns. For that purpose, we derive i) complete analytic description of time- and space-dependent size distribution of particles generated by a single immigrant; ii) the steady-state moments that correspond to multiple immigrants; and iii) size- and space-based asymptotic for the particle size distribution. Our results suggest a mechanism for universal premonitory patterns and provide a natural framework for their theoretical and empirical study.

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