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When black swans come in bunches: modelling the impact of temporal correlations on the return periods of heavy tailed risk

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For any natural hazard, the question of when the next “extreme event” (or “black swan”) is expected is of obvious importance. We here consider natural hazards defined in a very broad sense, as fluctuations in natural time series with the potential to pose a significant human or economic threat. In the environmental sciences users often frame such questions in terms of average “return periods”, e.g. “is an X meter rise in the Thames water level a 1-in-Y year event ?”. Frequently, however, we also care about the emergence of correlation, and whether the probability of several big events coming in close succession is truly independent, i.e. “bunched black swans”. We can thus see that a “big event”, or a “burst”, seen from the point of view of its integrated damage and loss, might be a single, very large, event, or, instead, could in fact be a correlated series of “smaller (i.e. less wildly fluctuating) events.

Several stochastic approaches exist that provide quantitative information about bursts. Some are more focused on the probability of single large events; others are more concerned with extended dwell times above a given spatiotemporal threshold: Extreme Value Theory (EVT); the theory of records; level sets; sojourn times; and models of “avalanches” in the non-Brownian space-time activity of non-equilibrium systems . However, the state of the art is not yet adequate for several reasons. Firstly, the above-mentioned approaches differ in fundamental aspects. The first group, EVT, is perhaps the best known of the above methods to geoscientists; it is used to derive and quantify, for example, the probability of exceedance for the failure of a dam. It is concerned with the distribution obeyed by the extremes of datasets, e.g. the 100 values obtained by considering the largest daily temperature recorded in each of the years of a century. However, the fundamental theorems on which EVT is built are based on independent identically distributed data and so take no account of memory and correlation that characterise many natural hazard time series; ignoring this fundamentally limits our ability to forecast. A second group of approaches, by contrast, explicitly has notions of time and thus possible nonstationarity built in. In record breaking statistics, a record is defined in the sense used in everyday language, to be the largest value yet recorded in a time series, for example, the Sumatran boxing day earthquake is the largest earthquake to be digitally recorded. The third group of approaches (e.g. avalanches) are explicitly spatiotemporal and so include spatial structure.

In practice which methods are adopted has also differed between, and within, application domains, sometimes reflecting data limitations. Although knowledge is understandably not yet integrated, nonetheless significant efforts have started along this direction. I will discuss an example of such unifying efforts & will show preliminary results [Watkins et al, PRE, 2009] ssing a standard model, linear fractional stable motion (LFSM), that explicitly includes *both* heavy tails and long range dependence, to study how these two effects contribute to the probability of large bursts in stochastic time series.