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Statistics and predictability of extreme events in the Lorenz 84 model driven by various processes

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In a well-known low-order chaotic model of global atmospheric circulation the effects of driving, i.e. time-dependent (periodic, chaotic, and noisy) forcing, are investigated, with particular interest in extremal behavior and its predictability. An approach based on snapshot attractors formed by a trajectory ensemble is applied to represent the time-dependent likelihood of peak-over-threshold extreme events in terms of a physical observable. A single trajectory-based framework, on the other hand, is used to determine the maximal value and the kurtosis of the distribution of the same observable. When the characteristic time scale of the driving becomes comparable to that of the model climate, we find that the magnitude, relative frequency, and variability of extremes is maximal. This appears to be a novel type of resonance.

Extreme value statistics is pursued by the method of block maxima, and found to follow Weibull distributions. Deterministic drivings result in shape parameters larger in modulus than stochastic drivings, but otherwise strongly dependent on the particular type of driving. The maximal effects of deterministic drivings are found to be more pronounced, both in magnitude and variability of the extremes, than white noise, and the latter has a stronger effect than red noise.

Peak-over-threshold extreme events are predicted in a probabilistic manner, using a long time series and based on precursors, and the goodness of the prediction is assessed in terms of Receiver Operating Characteristic (ROC) curves (comparing the rates of valid predictions and false alarms). This measure of predictability is compared to the more conventional finite-time Maximal Lyapunov Exponent, and their dependence on the threshold level and prediction lead-time is investigated. We find a characteristically different behaviour from simple stochastic processes, in terms of nontrivial/nonmonotonic dependences.