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Estimating return times with rare event algorithms

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A metric typically used to discuss extreme events, such as floods, heat waves and other natural hazards, is the return time of the event. However, estimating return times for rare events directly from observational or numerical data is a very difficult task, because extremely long time series are necessary.
Here, I will present a method to efficiently compute return times based on the equations (deterministic or stochastic) governing the dynamics of the system.

This method relies on rare event algorithms, designed to estimate small probabilities by evolving a population of clones of the system according to selection rules biased (in a controlled way) to favor the appearance of the desired rare event.
More precisely, we combine the fact that, for a Poisson process, return times are related to the probability of observing extrema over pieces of trajectories, and the observation that several classes of rare event algorithms can be easily generalized to compute the probability of extrema over pieces of trajectories, to estimate return times in an elementary way with simple and robust algorithms.

I shall illustrate this approach by computing return times, with two different algorithms — Adaptive Multilevel Splitting and the Giardina-Kurchan algorithm — for a low-dimensional stochastic system, the Ornstein-Uhlenbeck process, for both instantaneous and time-averaged observables. The method allows to reduce the computational cost by several orders of magnitude compared to direct estimate; this opens new prospects for studying extreme events, such as heat waves, in a statistical manner.